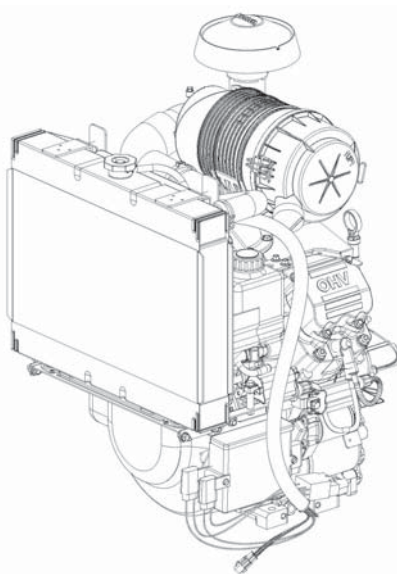


KOHLER Aegis®

LH775

Service Manual



IMPORTANT: Read all safety precautions and instructions carefully before operating equipment. Refer to operating instruction of equipment that this engine powers.

Ensure engine is stopped and level before performing any maintenance or service.

2	Safety
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Safety


SAFETY PRECAUTIONS


⚠ WARNING: A hazard that could result in death, serious injury, or substantial property damage.


⚠ CAUTION: A hazard that could result in minor personal injury or property damage.


NOTE: is used to notify people of important installation, operation, or maintenance information.

	<p>⚠ WARNING</p> <p>Explosive Fuel can cause fires and severe burns.</p> <p>Do not fill fuel tank while engine is hot or running.</p>
<p>Gasoline is extremely flammable and its vapors can explode if ignited. Store gasoline only in approved containers, in well ventilated, unoccupied buildings, away from sparks or flames. Spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Never use gasoline as a cleaning agent.</p>	


	<p>⚠ WARNING</p> <p>Rotating Parts can cause severe injury.</p> <p>Stay away while engine is in operation.</p>
<p>Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate engine with covers, shrouds, or guards removed.</p>	


	<p>⚠ WARNING</p> <p>Carbon Monoxide can cause severe nausea, fainting or death.</p> <p>Avoid inhaling exhaust fumes.</p>
<p>Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.</p>	

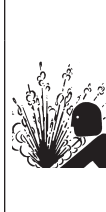
	<p>⚠ WARNING</p> <p>Accidental Starts can cause severe injury or death.</p> <p>Disconnect and ground spark plug lead(s) before servicing.</p>
<p>Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug lead(s). 2) Disconnect negative (–) battery cable from battery.</p>	


	<p>⚠ WARNING</p> <p>Hot Parts can cause severe burns.</p> <p>Do not touch engine while operating or just after stopping.</p>
<p>Never operate engine with heat shields or guards removed.</p>	

	<p>⚠ WARNING</p> <p>Cleaning Solvents can cause severe injury or death.</p> <p>Use only in well ventilated areas away from ignition sources.</p>
<p>Carburetor cleaners and solvents are extremely flammable. Follow cleaner manufacturer's warnings and instructions on its proper and safe use. Never use gasoline as a cleaning agent.</p>	


	<p>⚠ CAUTION</p> <p>Electrical Shock can cause injury.</p> <p>Do not touch wires while engine is running.</p>
---	--

	<p>⚠ CAUTION</p> <p>Damaging Crankshaft and Flywheel Can Cause Personal Injury!</p>
<p>Using improper procedures can lead to broken fragments. Broken fragments could be thrown from engine. Always observe and use precautions and procedures when installing flywheel.</p>	

	<p>⚠ WARNING</p> <p>Hot liquid can cause severe burns.</p> <p>Do not loosen radiator cap while engine is operating or warm to touch.</p>
<p>Liquid coolant can get extremely hot from operation. Turning radiator cap when engine is hot can allow steam and scalding liquid to blow out and burn you severely. Shut off machine. Only remove radiator cap when cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing completely.</p>	

	<p>⚠ WARNING</p> <p>Explosive Fuel can cause fires and severe burns.</p> <p>Fuel system ALWAYS remains under HIGH PRESSURE.</p>
<p>Wrap a shop towel completely around fuel pump module connector. Press release button(s) and slowly pull connector away from fuel pump module allowing shop towel to absorb any residual fuel in high pressure fuel line. Any spilled fuel must be completely wiped up immediately.</p>	

MAINTENANCE INSTRUCTIONS

	<p>⚠ WARNING</p> <p>Accidental Starts can cause severe injury or death.</p> <p>Disconnect and ground spark plug lead(s) before servicing.</p>	<p>Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug lead(s). 2) Disconnect negative (–) battery cable from battery.</p>
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Normal maintenance, replacement or repair of emission control devices and systems may be performed by any repair establishment or individual; however, warranty repairs must be performed by a Kohler authorized dealer.

MAINTENANCE SCHEDULE

Every 200 Hours¹

<ul style="list-style-type: none"> Change oil and oil filter. 	Lubrication System
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Every 200 Hours

<ul style="list-style-type: none"> Replace fuel filter.
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Every 250 Hours¹

<ul style="list-style-type: none"> Replace air cleaner element and check inner element. 	Air Cleaner/Intake
--	--------------------

Every 500 Hours¹

<ul style="list-style-type: none"> Replace air cleaner inner element. 	Air Cleaner/Intake
--	--------------------

Every 500 Hours

<ul style="list-style-type: none"> Replace spark plugs and set gap. 	Electrical System
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Every 1000 Hours

<ul style="list-style-type: none"> Change engine coolant. 	Cooling System
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Every 1500 Hours¹

<ul style="list-style-type: none"> Replace unique Electronic Fuel Injection (EFI) fuel filter.

¹ Perform these procedures more frequently under severe, dusty, dirty conditions.

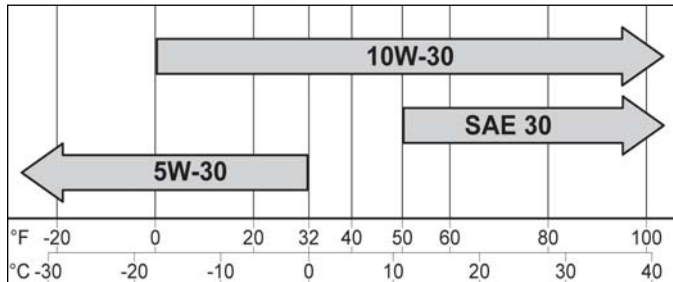
REPAIRS/SERVICE PARTS

Kohler genuine service parts can be purchased from Kohler authorized dealers. Find your local Kohler Engines dealer at KohlerEngines.com or call 1-800-544-2444 (U.S.A. and Canada).


Maintenance

OIL RECOMMENDATIONS

We recommend use of Kohler oils for best performance. Other high-quality detergent oils (including synthetic) of API (American Petroleum Institute) service class SJ or higher are acceptable. Select viscosity based on air temperature at time of operation as shown in table below.



FUEL RECOMMENDATIONS

	⚠ WARNING
	Explosive Fuel can cause fires and severe burns.
	Do not fill fuel tank while engine is hot or running.

Gasoline is extremely flammable and its vapors can explode if ignited. Store gasoline only in approved containers, in well ventilated, unoccupied buildings, away from sparks or flames. Spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Never use gasoline as a cleaning agent.

NOTE: E15, E20 and E85 are NOT approved and should NOT be used; effects of old, stale or contaminated fuel are not warrantable.

Fuel must meet these requirements:

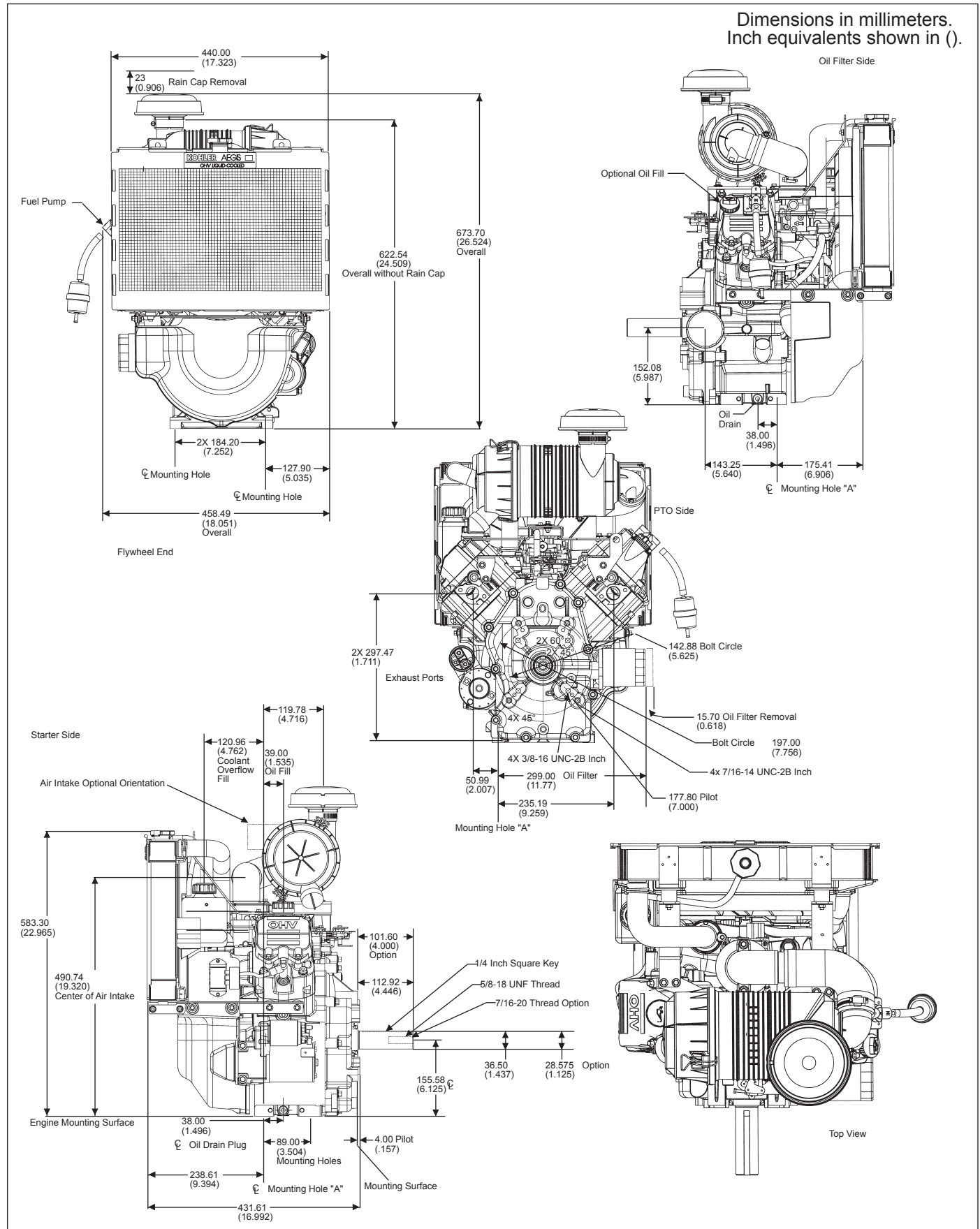
- Clean, fresh, unleaded gasoline.
- Octane rating of 87 (R+M)/2 or higher.
- Research Octane Number (RON) 90 octane minimum.
- Gasoline up to 10% ethyl alcohol, 90% unleaded is acceptable.
- Methyl Tertiary Butyl Ether (MTBE) and unleaded gasoline blend (max 15% MTBE by volume) are approved.
- Do not add oil to gasoline.
- Do not overfill fuel tank.
- Do not use gasoline older than 30 days.

STORAGE

If engine will be out of service for 2 months or more follow procedure below.

1. Add Kohler PRO Series fuel treatment or equivalent to fuel tank. Run engine 2-3 minutes to get stabilized fuel into fuel system (failures due to untreated fuel are not warrantable).
2. Change oil while engine is still warm from operation. Remove spark plug(s) and pour about 1 oz. of engine oil into cylinder(s). Replace spark plug(s) and crank engine slowly to distribute oil.
3. Disconnect negative (-) battery cable.
4. Store engine in a clean, dry place.

Engine Dimensions



Specifications

ENGINE IDENTIFICATION NUMBERS

Kohler engine identification numbers (model, specification and serial) should be referenced for efficient repair, ordering correct parts, and engine replacement.

Model	LH775
Liquid Cooled	—
Horizontal Shaft	—
Numerical Designation	—
Specification	LH775-0001
Serial	3923500328
Year Manufactured Code	—
Factory Code	—
Code	Year
39	2009
40	2010
41	2011

GENERAL SPECIFICATIONS^{3,6}

LH775

Bore	83 mm (3.3 in.)
Stroke	69 mm (2.7 in.)
Displacement	747 cc (45.6 cu. in.)
Oil Capacity (refill)	1.6-1.8 L (1.7-1.9 U.S. qt.)
Maximum Angle of Operation (@ full oil level) ⁴	20°

TORQUE SPECIFICATIONS^{3,5}

LH775

Intake Manifold

Intake Manifold Fastener (torque in 2 increments)	first to 7.4 N·m (66 in. lb.) finally to 9.9 N·m (88 in. lb.)
Thermostat Housing Mounting Fastener	6.2-7.3 N·m (55-65 in. lb.)
Air Cleaner Elbow Mounting Fastener	9.9 N·m (88 in. lb.)

Closure Plate

Closure Plate Fastener	24.4 N·m (216 in. lb.)
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Connecting Rod

Cap Fastener (torque in increments)	11.3 N·m (100 in. lb.)
-------------------------------------	------------------------

Crankcase

Breather Cover Fastener	10.7 N·m (95 in. lb.) into new hole 7.3 N·m (65 in. lb.) into used hole
Oil Drain Plug	13.6 N·m (10 ft . lb.)

Cylinder Head

Cylinder Head Fastener (torque in 2 increments)	first to 16.9 N·m (150 in. lb.) finally to 33.9 N·m (300 in. lb.)
Rocker Pivot Fastener	11.3 N·m (100 in. lb.)

³ Values are in Metric units. Values in parentheses are English equivalents.

⁴ Exceeding maximum angle of operation may cause engine damage from insufficient lubrication.

⁵ Lubricate threads with engine oil prior to assembly.

⁶ Any and all horsepower (hp) references by Kohler are Certified Power Ratings and per SAE J1940 & J1995 hp standards. Details on Certified Power Ratings can be found at KohlerEngines.com.

TORQUE SPECIFICATIONS^{3,5}

LH775

Electric Starter

Starter Thru Bolt	5.6-9.0 N·m (49-79 in. lb.)
Starter Mounting Screw	15.3 N·m (135 in. lb.)
Starter Brush Holder Fastener	2.5-3.3 N·m (22-29 in. lb.)
Starter Solenoid Fastener	4.0-6.0 N·m (35-53 in. lb.)
Starter Solenoid Positive (+) Brush Lead Retaining Nut	8.0-11.0 N·m (71-97 in. lb.)

Fan/Flywheel

Rear Fan Shaft to Mounting Bracket Nut	15.8 N·m (140 in. lb.)
Front Fan Assembly to Fan Shaft Nut	15.8 N·m (140 in. lb.)
Fan/Pulley/Hub Assembly Fastener	6.8 N·m (60 in. lb.)
Flywheel Retaining Screw	66.4 N·m (49 ft. lb.)
Lower Flywheel Cover Mounting Screw	into hex or weld nuts 9.9 N·m (88 in. lb.) into Timmerman clips/nuts 2.2-2.8 N·m (20-25 in. lb.)
Lower Pulley Mounting Screw	24.3 N·m (215 in. lb.)

Governor

Governor Lever Nut	6.8 N·m (60 in. lb.)
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Ignition

Spark Plug	27 N·m (20 ft. lb.)
Ignition Module Fastener	6.2 N·m (55 in. lb.) into new hole 4.0 N·m (35 in. lb.) into used hole
Rectifier-Regulator Fastener	4.0 N·m (35 in. lb.)

Muffler

Muffler Retaining Nuts	24.4 N·m (216 in. lb.)
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Speed Control

Speed Control Bracket Assembly Fastener	10.7 N·m (95 in. lb.) into new holes 7.3 N·m (65 in. lb.) into used holes
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Stator

Stator Mounting Screw	6.2 N·m (55 in. lb.)
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Valve Cover/Rocker Arms

Valve Cover Fastener	6.2 N·m (55 in. lb.)
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Water Pump

Mounting Screw	9.9 N·m (88 in. lb.)
Pulley Mounting Screw	9.9 N·m (88 in. lb.)

CLEARANCE SPECIFICATIONS³

LH775

Camshaft

End Play (with shim)	0.076/0.127 mm (0.0030/0.0050 in.)
Running Clearance	0.025/0.063 mm (0.0010/0.0025 in.)
Bore I.D. New Max. Wear Limit	20.000/20.025 mm (0.7874/0.7884 in.) 20.038 mm (0.7889 in.)
Camshaft Bearing Surface O.D. New Max. Wear Limit	19.962/19.975 mm (0.7859/0.7864 in.) 19.959 mm (0.7858 in.)

³ Values are in Metric units. Values in parentheses are English equivalents.

⁵ Lubricate threads with engine oil prior to assembly.

Specifications

CLEARANCE SPECIFICATIONS³

LH775

Connecting Rod

Connecting Rod-to-Crankpin Running Clearance New Max. Wear Limit	0.043/0.068 mm (0.0016/0.0026 in.) 0.083 mm (0.0032 in.)
Connecting Rod-to-Crankpin Side Clearance	0.26/0.63 mm (0.0102/0.0248 in.)
Connecting Rod-to-Piston Pin Running Clearance	0.015/0.028 mm (0.0006/0.0011 in.)

Crankcase

Governor Cross Shaft Bore I.D. New Max. Wear Limit	8.025/8.075 mm (0.3159/0.3179 in.) 8.088 mm (0.3184 in.)
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Crankshaft

End Play (free)	0.070/0.590 mm (0.0028/0.0230 in.)
Crankshaft Sleeve Bearing I.D. (crankcase) New Max. Wear Limit	40.974/40.987 mm (1.6131/1.6136 in.) 41.000 mm (1.6141 in.)
Crankshaft Bore (in closure plate) New Max. Wear Limit	40.974/41.000 mm (1.6131/1.6141 in.) 41.038 mm (1.6156 in.)
Crankshaft Bore (in closure plate)-to-Crankshaft Running Clearance New	0.039/0.087 mm (0.0015/0.0034 in.)
Main Bearing Journals O.D. - New O.D. - Max. Wear Limit Max. Taper Max. Out-of-Round	40.913/40.935 mm (1.6107/1.6116 in.) 40.84 mm (1.608 in.) 0.022 mm (0.0009 in.) 0.025 mm (0.0010 in.)
Crankshaft to Sleeve Bearing (crankcase) Running Clearance New	0.039/0.074 mm (0.0015/0.0029 in.)
Connecting Rod Journal O.D. - New O.D. - Max. Wear Limit Max. Taper Max. Out-of-Round	35.955/35.973 mm (1.4156/1.4163 in.) 35.94 mm (1.415 in.) 0.018 mm (0.0007 in.) 0.025 mm (0.0010 in.)
Crankshaft T.I.R. PTO End, Crank in Engine Entire Crank, in V-Blocks	0.15 mm (0.0059 in.) 0.10 mm (0.0039 in.)

Cylinder Bore

Cylinder Bore I.D. New Max. Wear Limit	83.006/83.031 mm (3.2679/3.2689 in.) 83.069 mm (3.2704 in.)
Max. Out-of-Round Max. Taper	0.12 mm (0.0047 in.) 0.05 mm (0.0020 in.)

Cylinder Head

Max. Out-of-Flatness	0.076 mm (0.003 in.)
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³Values are in Metric units. Values in parentheses are English equivalents.

CLEARANCE SPECIFICATIONS³

LH775

Governor

Governor Cross Shaft to Crankcase Running Clearance	0.025/0.126 mm (0.0009/0.0049 in.)
Governor Cross Shaft O.D. New Max. Wear Limit	7.949/8.000 mm (0.3129/0.3149 in.) 7.936 mm (0.3124 in.)
Governor Gear Shaft O.D. New Max. Wear Limit	5.990/6.000 mm (0.2358/0.2362 in.) 5.977 mm (0.2353 in.)
Governor Gear Shaft -to-Governor Gear Running Clearance	0.090/0.160 mm (0.0035/0.0063 in.)

Ignition

Spark Plug Gap	0.76 mm (0.030 in.)
Ignition Module Air Gap	0.203/0.305 mm (0.008/0.012 in.)

Piston, Piston Rings, and Piston Pin

Piston-to-Piston Pin	0.006/0.018 mm (0.0002/0.0007 in.)
Piston Pin Bore I.D. New Max. Wear Limit	17.006/17.013 mm (0.6695/0.6698 in.) 17.025 mm (0.6703 in.)
Piston Pin O.D. New Max. Wear Limit	16.995/17.000 mm (0.6691/0.6693 in.) 16.994 mm (0.6691 in.)
Top Compression Ring-to-Groove Side Clearance	0.014/0.041 mm (0.0005/0.0016 in.)
Middle Compression Ring-to-Groove Side Clearance	0.012/0.039 mm (0.0004/0.0015 in.)
Oil Control Ring-to-Groove Side Clearance	0.026/0.176 mm (0.0010/0.0070 in.)
Top and Middle Compression Ring End Gap New Bore	0.250/0.56 mm (0.0098/0.022 in.)
Used Bore (Max.)	0.94 mm (0.037 in.)
Piston Thrust Face O.D. ⁷ New	82.973/82.991 mm (3.2666/3.2673 in.)
Max. Wear Limit	82.841 mm (3.3136 in.)
Piston Thrust Face-to-Cylinder Bore ⁷ Running Clearance	0.015/0.058 mm (0.0005/0.0022 in.)

Valves and Valve Lifters

Hydraulic Valve Lift er to Crankcase Running Clearance	0.0124/0.0501 mm (0.0005/0.0020 in.)
Intake Valve Stem-to-Valve Guide Running Clearance	0.038/0.076 mm (0.0015/0.0030 in.)
Exhaust Valve Stem-to-Valve Guide Running Clearance	0.050/0.088 mm (0.0020/0.0035 in.)
Intake Valve Guide I.D. New Max. Wear Limit	7.038/7.058 mm (0.2771/0.2779 in.) 7.134 mm (0.2809 in.)
Intake Valve Stem Diameter New	6.982/7.000 mm (0.2749/0.2756 in.)
Exhaust Valve Guide I.D. New Max. Wear Limit	7.038/7.058 mm (0.2771/0.2779 in.) 7.159 mm (0.2819 in.)
Exhaust Valve Stem Diameter New	6.970/6.988 mm (0.2744/0.2751 in.)
Valve Guide Reamer Size Standard 0.25 mm O.S.	7.048 mm (0.2775 in.) 7.298 mm (0.2873 in.)
Intake Valve Lift	8.88 mm (0.3496 in.)
Exhaust Valve Lift	8.88 mm (0.3496 in.)
Nominal Valve Seat Angle	45°






³ Values are in Metric units. Values in parentheses are English equivalents.

⁷ Measure 6 mm (0.236 in.) above bottom of piston skirt at right angles to piston pin.

Specifications

GENERAL TORQUE VALUES






English Fastener Torque Recommendations for Standard Applications

Bolts, Screws, Nuts and Fasteners Assembled Into Cast Iron or Steel				Grade 2 or 5 Fasteners Into Aluminum
Size	 Grade 2	 Grade 5	 Grade 8	 
Tightening Torque: N·m (in. lb.) ± 20%				
8-32	2.3 (20)	2.8 (25)	—	2.3 (20)
10-24	3.6 (32)	4.5 (40)	—	3.6 (32)
10-32	3.6 (32)	4.5 (40)	—	—
1/4-20	7.9 (70)	13.0 (115)	18.7 (165)	7.9 (70)
1/4-28	9.6 (85)	15.8 (140)	22.6 (200)	—
5/16-18	17.0 (150)	28.3 (250)	39.6 (350)	17.0 (150)
5/16-24	18.7 (165)	30.5 (270)	—	—
3/8-16	29.4 (260)	—	—	—
3/8-24	33.9 (300)	—	—	—

Tightening Torque: N·m (ft. lb.) ± 20%

5/16-24	—	—	40.7 (30)	—
3/8-16	—	47.5 (35)	67.8 (50)	—
3/8-24	—	54.2 (40)	81.4 (60)	—
7/16-14	47.5 (35)	74.6 (55)	108.5 (80)	—
7/16-20	61.0 (45)	101.7 (75)	142.5 (105)	—
1/2-13	67.8 (50)	108.5 (80)	155.9 (115)	—
1/2-20	94.9 (70)	142.4 (105)	223.7 (165)	—
9/16-12	101.7 (75)	169.5 (125)	237.3 (175)	—
9/16-18	135.6 (100)	223.7 (165)	311.9 (230)	—
5/8-11	149.5 (110)	244.1 (180)	352.6 (260)	—
5/8-18	189.8 (140)	311.9 (230)	447.5 (330)	—
3/4-10	199.3 (147)	332.2 (245)	474.6 (350)	—
3/4-16	271.2 (200)	440.7 (325)	637.3 (470)	—

Metric Fastener Torque Recommendations for Standard Applications

Size	Property Class					Noncritical Fasteners Into Aluminum
	 4.8	 5.8	 8.8	 10.9	 12.9	
Tightening Torque: N·m (in. lb.) ± 10%						
M4	1.2 (11)	1.7 (15)	2.9 (26)	4.1 (36)	5.0 (44)	2.0 (18)
M5	2.5 (22)	3.2 (28)	5.8 (51)	8.1 (72)	9.7 (86)	4.0 (35)
M6	4.3 (38)	5.7 (50)	9.9 (88)	14.0 (124)	16.5 (146)	6.8 (60)
M8	10.5 (93)	13.6 (120)	24.4 (216)	33.9 (300)	40.7 (360)	17.0 (150)

Tightening Torque: N·m (ft. lb.) ± 10%

M10	21.7 (16)	27.1 (20)	47.5 (35)	66.4 (49)	81.4 (60)	33.9 (25)
M12	36.6 (27)	47.5 (35)	82.7 (61)	116.6 (86)	139.7 (103)	61.0 (45)
M14	58.3 (43)	76.4 (56)	131.5 (97)	184.4 (136)	219.7 (162)	94.9 (70)

Torque Conversions

N·m = in. lb. x 0.113	in. lb. = N·m x 8.85
N·m = ft. lb. x 1.356	ft. lb. = N·m x 0.737

Certain quality tools are designed to help you perform specific disassembly, repair, and reassembly procedures. By using these tools, you can properly service engines easier, faster, and safer! In addition, you'll increase your service capabilities and customer satisfaction by decreasing engine downtime.

Here is a list of tools and their source.

SEPARATE TOOL SUPPLIERS

Kohler Tools
Contact your local Kohler source of supply.

SE Tools
415 Howard St.
Lapeer, MI 48446
Phone 810-664-2981
Toll Free 800-664-2981
Fax 810-664-8181

Design Technology Inc.
768 Burr Oak Drive
Westmont, IL 60559
Phone 630-920-1300
Fax 630-920-0011

TOOLS

Description	Source/Part No.
Alcohol Content Tester For testing alcohol content (%) in reformulated/oxygenated fuels.	Kohler 25 455 11-S
Camshaft Endplay Plate For checking camshaft endplay.	SE Tools KLR-82405
Camshaft Seal Protector (Aegis) For protecting seal during camshaft installation.	SE Tools KLR-82417
Cylinder Leakdown Tester For checking combustion retention and if cylinder, piston, rings, or valves are worn. Individual component available: Adapter 12 mm x 14 mm (Required for leakdown test on XT-6 engines)	Kohler 25 761 05-S Design Technology Inc. DTI-731-03
Dealer Tool Kit (Domestic) Complete kit of Kohler required tools. Components of 25 761 39-S Ignition System Tester Cylinder Leakdown Tester Oil Pressure Test Kit Rectifier-Regulator Tester (120 V AC/60Hz)	Kohler 25 761 39-S Kohler 25 455 01-S Kohler 25 761 05-S Kohler 25 761 06-S Kohler 25 761 20-S
Dealer Tool Kit (International) Complete kit of Kohler required tools. Components of 25 761 42-S Ignition System Tester Cylinder Leakdown Tester Oil Pressure Test Kit Rectifier-Regulator Tester (240 V AC/50Hz)	Kohler 25 761 42-S Kohler 25 455 01-S Kohler 25 761 05-S Kohler 25 761 06-S Kohler 25 761 41-S
Digital Vacuum/Pressure Tester For checking crankcase vacuum. Individual component available: Rubber Adapter Plug	Design Technology Inc. DTI-721-01 Design Technology Inc. DTI-721-10
Electronic Fuel Injection (EFI) Diagnostic Software For Laptop or Desktop PC.	Kohler 25 761 23-S
EFI Service Kit For troubleshooting and setting up an EFI engine. Components of 24 761 01-S Fuel Pressure Tester Noid Light 90° Adapter In-line "T" Fitting Code Plug, Red Wire Code Plug, Blue Wire Shrader Valve Adapter Hose	Kohler 24 761 01-S Design Technology Inc. DTI-019 DTI-021 DTI-023 DTI-035 DTI-027 DTI-029 DTI-037
Flywheel Holding Tool (CS) For holding flywheel of CS series engines.	SE Tools KLR-82407
Flywheel Puller For properly removing flywheel from engine.	SE Tools KLR-82408
Flywheel Strap Wrench For holding flywheel during removal.	SE Tools KLR-82409

Tools and Aids

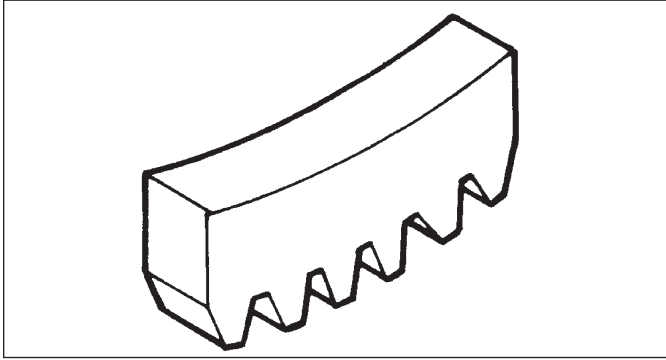
TOOLS

Description	Source/Part No.
Hydraulic Valve Lifter Tool For removing and installing hydraulic lifters.	Kohler 25 761 38-S
Ignition System Tester For testing output on all systems, including CD.	Kohler 25 455 01-S
Inductive Tachometer (Digital) For checking operating speed (RPM) of an engine.	Design Technology Inc. DTI-110
Offset Wrench (K and M Series) For removing and reinstalling cylinder barrel retaining nuts.	Kohler 52 455 04-S
Oil Pressure Test Kit For testing/verifying oil pressure on pressure lubricated engines.	Kohler 25 761 06-S
Radiator Tester For pressure testing radiator and cap on Aegis liquid-cooled engines.	Kohler 25 455 10-S
Rectifier-Regulator Tester (120 volt current) Rectifier-Regulator Tester (240 volt current) For testing rectifier-regulators. Components of 25 761 20-S and 25 761 41-S CS-PRO Regulator Test Harness Special Regulator Test Harness with Diode	Kohler 25 761 20-S Kohler 25 761 41-S Design Technology Inc. DTI-031 DTI-033
Spark Advance Module (SAM) Tester For testing SAM (ASAM and DSAM) on engines with SMART-SPARK™.	Kohler 25 761 40-S
Starter Servicing Kit (All Starters) For removing and reinstalling drive retaining rings and brushes. Individual component available: Starter Brush Holding Tool (Solenoid Shift)	SE Tools KLR-82411 SE Tools KLR-82416
Triad/OHC Timing Tool Set For holding cam gears and crankshaft in timed position while installing timing belt.	Kohler 28 761 01-S
Valve Guide Reamer (K and M Series) For properly sizing valve guides after installation.	Design Technology Inc. DTI-K828
Valve Guide Reamer O.S. (Command Series) For reaming worn valve guides to accept replacement oversize valves. Can be used in low-speed drill press or with handle below for hand reaming.	Kohler 25 455 12-S
Reamer Handle For hand reaming using Kohler 25 455 12-S reamer.	Design Technology Inc. DTI-K830
Valve Guide Service Kit (Courage, Aegis, Command, OHC) For servicing worn valve guides.	SE Tools KLR-82415

AIDS

Description	Source/Part No.
Camshaft Lubricant (Valspar ZZ613)	Kohler 25 357 14-S
Dielectric Grease (GE/Novaguard G661)	Kohler 25 357 11-S
Dielectric Grease	Loctite® 51360
Kohler Electric Starter Drive Lubricant (Inertia Drive)	Kohler 52 357 01-S
Kohler Electric Starter Drive Lubricant (Solenoid Shift)	Kohler 52 357 02-S
RTV Silicone Sealant Loctite® 5900® Heavy Body in 4 oz. aerosol dispenser. Only oxime-based, oil resistant RTV sealants, such as those listed, are approved for use. Loctite® Nos. 5900® or 5910® are recommended for best sealing characteristics.	Kohler 25 597 07-S Loctite® 5910® Loctite® Ultra Black 598™ Loctite® Ultra Blue 587™ Loctite® Ultra Copper 5920™
Spline Drive Lubricant	Kohler 25 357 12-S

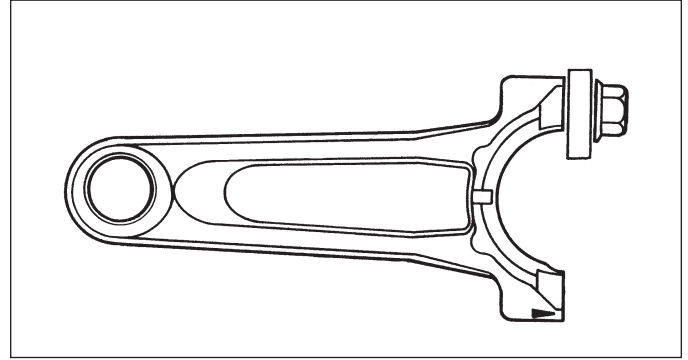
FLYWHEEL HOLDING TOOL



A flywheel holding tool can be made out of an old junk flywheel ring gear and used in place of a strap wrench.

1. Using an abrasive cut-off wheel, cut out a six tooth segment of ring gear as shown.
2. Grind off any burrs or sharp edges.
3. Invert segment and place it between ignition bosses on crankcase so tool teeth engage flywheel ring gear teeth. Bosses will lock tool and flywheel in position for loosening, tightening, or removing with a puller.

ROCKER ARM/CRANKSHAFT TOOL



A spanner wrench to lift rocker arms or turn crankshaft may be made out of an old junk connecting rod.

1. Find a used connecting rod from a 10 HP or larger engine. Remove and discard rod cap.
2. Remove studs of a Posi-Lock rod or grind off aligning steps of a Command rod, so joint surface is flat.
3. Find a 1 in. long cap screw with correct thread size to match threads in connecting rod.
4. Use a flat washer with correct I.D. to slip on cap screw and approximately 1 in. O.D. Assemble cap screw and washer to joint surface of rod.

Troubleshooting

TROUBLESHOOTING GUIDE

When troubles occur, be sure to check simple causes which, at first, may seem too obvious to be considered. For example, a starting problem could be caused by an empty fuel tank.

Some general common causes of engine troubles are listed below and vary by engine specification. Use these to locate causing factors.

Engine Cranks But Will Not Start

- Battery connected backwards.
- Blown fuse.
- Carburetor solenoid malfunction.
- Choke not closing.
- Clogged fuel line or fuel filter.
- Diode in wiring harness failed in open circuit mode.
- DSAI or DSAM malfunction.
- Empty fuel tank.
- Faulty electronic control unit.
- Faulty ignition coil(s).
- Faulty spark plug(s).
- Fuel pump malfunction-vacuum hose clogged or leaking.
- Fuel shut-off valve closed.
- Ignition module(s) faulty or improperly gapped.
- Insufficient voltage to electronic control unit.
- Interlock switch is engaged or faulty.
- Key switch or kill switch in OFF position.
- Low oil level.
- Quality of fuel (dirt, water, stale, mixture).
- SMART-SPARK™ malfunction.
- Spark plug lead(s) disconnected.

Engine Starts But Does Not Keep Running

- Faulty carburetor.
- Faulty cylinder head gasket.
- Faulty or misadjusted choke or throttle controls.
- Fuel pump malfunction-vacuum hose clogged or leaking.
- Intake system leak.
- Loose wires or connections that intermittently ground ignition kill circuit.
- Quality of fuel (dirt, water, stale, mixture).
- Restricted fuel tank cap vent.

Engine Starts Hard

- Clogged fuel line or fuel filter.
- Engine overheated.
- Faulty ACR mechanism.
- Faulty or misadjusted choke or throttle controls.
- Faulty spark plug(s).
- Flywheel key sheared.
- Fuel pump malfunction-vacuum hose clogged or leaking.
- Interlock switch is engaged or faulty.
- Loose wires or connections that intermittently ground ignition kill circuit.
- Low compression.
- Quality of fuel (dirt, water, stale, mixture).
- Weak spark.

Engine Will Not Crank

- Battery is discharged.
- Faulty electric starter or solenoid.
- Faulty key switch or ignition switch.
- Interlock switch is engaged or faulty.
- Loose wires or connections that intermittently ground ignition kill circuit.
- Pawls not engaging in drive cup.
- Seized internal engine components.

Engine Runs But Misses

- Carburetor adjusted incorrectly.
- Engine overheated.
- Faulty spark plug(s).
- Ignition module(s) faulty or improperly gapped.
- Incorrect crankshaft position sensor air gap.
- Interlock switch is engaged or faulty.
- Loose wires or connections that intermittently ground ignition kill circuit.
- Quality of fuel (dirt, water, stale, mixture).
- Spark plug lead(s) disconnected.
- Spark plug lead boot loose on plug.
- Spark plug lead loose.

Engine Will Not Idle

- Engine overheated.
- Faulty spark plug(s).
- Idle fuel adjusting needle(s) improperly set.
- Idle speed adjusting screw improperly set.
- Inadequate fuel supply.
- Low compression.
- Quality of fuel (dirt, water, stale, mixture).
- Restricted fuel tank cap vent.

Engine Overheats

- Cooling fan broken.
- Excessive engine load.
- Fan belt failed/off.
- Faulty carburetor.
- High crankcase oil level.
- Lean fuel mixture.
- Low cooling system fluid level.
- Low crankcase oil level.
- Radiator, and/or cooling system components clogged, restricted, or leaking.
- Water pump belt failed/broken.
- Water pump malfunction.

Engine Knocks

- Excessive engine load.
- Hydraulic lifter malfunction.
- Incorrect oil viscosity/type.
- Internal wear or damage.
- Low crankcase oil level.
- Quality of fuel (dirt, water, stale, mixture).

Engine Loses Power

- Dirty air cleaner element.
- Engine overheated.
- Excessive engine load.
- Restricted exhaust.
- Faulty spark plug(s).
- High crankcase oil level.
- Incorrect governor setting.
- Low battery.
- Low compression.
- Low crankcase oil level.
- Quality of fuel (dirt, water, stale, mixture).

Engine Uses Excessive Amount of Oil

- Loose or improperly torqued fasteners.
- Blown head gasket/overheated.
- Breather reed broken.
- Clogged, broken, or inoperative crankcase breather.
- Crankcase overfilled.
- Incorrect oil viscosity/type.
- Worn cylinder bore.
- Worn or broken piston rings.
- Worn valve stems/valve guides.

Oil Leaks from Oil Seals, Gaskets

- Breather reed broken.
- Clogged, broken, or inoperative crankcase breather.
- Loose or improperly torqued fasteners.
- Piston blow by, or leaky valves.
- Restricted exhaust.

EXTERNAL ENGINE INSPECTION


NOTE: It is good practice to drain oil at a location away from workbench. Be sure to allow ample time for complete drainage.

Before cleaning or disassembling engine, make a thorough inspection of its external appearance and condition. This inspection can give clues to what might be found inside engines (and cause) when it is disassembled.

- Check for buildup of dirt and debris on crankcase, cooling fins, grass screen, and other external surfaces. Dirt or debris on these areas can cause overheating.
- Check for obvious fuel and oil leaks, and damaged components. Excessive oil leakage can indicate a clogged or inoperative breather, worn or damaged seals or gaskets, or loose fasteners.
- Check air cleaner cover and base for damage or indications of improper fit and seal.
- Check air cleaner element. Look for holes, tears, cracked or damaged sealing surfaces, or other damage that could allow unfiltered air into engine. A dirty or clogged element could indicate insufficient or improper maintenance.
- Check carburetor throat for dirt. Dirt in throat is further indication that air cleaner was not functioning properly.
- Check if oil level is within operating range on dipstick. If it is above, sniff for gasoline odor.
- Check condition of oil. Drain oil into a container; it should flow freely. Check for metal chips and other foreign particles.

Sludge is a natural by-product of combustion; a small accumulation is normal. Excessive sludge formation could indicate over rich fuel settings, weak ignition, overextended oil change interval or wrong weight or type of oil was used.

CLEANING ENGINE


	⚠ WARNING
	<p>Cleaning Solvents can cause severe injury or death.</p> <p>Use only in well ventilated areas away from ignition sources.</p>
<p>Carburetor cleaners and solvents are extremely flammable. Follow cleaner manufacturer's warnings and instructions on its proper and safe use. Never use gasoline as a cleaning agent.</p>	


After inspecting external condition of engine, clean engine thoroughly before disassembly. Clean individual components as engine is disassembled. Only clean parts can be accurately inspected and gauged for wear or damage. There are many commercially available cleaners that will quickly remove grease, oil, and grime from engine parts. When such a cleaner is used, follow manufacturer's instructions and safety precautions carefully.

Make sure all traces of cleaner are removed before engine is reassembled and placed into operation. Even small amounts of these cleaners can quickly break down lubricating properties of engine oil.

Troubleshooting

CRANKCASE VACUUM TEST

	<p>⚠ WARNING</p> <p>Carbon Monoxide can cause severe nausea, fainting or death. Avoid inhaling exhaust fumes.</p>
	<p>Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.</p>

	<p>⚠ WARNING</p> <p>Rotating Parts can cause severe injury. Stay away while engine is in operation.</p>
	<p>Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate engine with covers, shrouds, or guards removed.</p>

A partial vacuum should be present in crankcase when engine is operating. Pressure in crankcase (normally caused by a clogged or improperly assembled breather) can cause oil to be forced out at oil seals, gaskets, or other available spots.

Crankcase vacuum is best measured with either a water manometer or a vacuum gauge. Complete instructions are provided in kits.

To test crankcase vacuum with manometer:

1. Insert rubber stopper into oil fill hole. Be sure pinch clamp is installed on hose and use tapered adapters to connect hose between stopper and one manometer tube. Leave other tube open to atmosphere. Check that water level in manometer is at 0 line. Make sure pinch clamp is closed.
2. Start engine and run no-load high speed.
3. Open clamp and note water level in tube.
Level in engine side should be a minimum of 10.2 cm (4 in.) above level in open side.
If level in engine side is less than specified (low/no vacuum), or level in engine side is lower than level in open side (pressure), check for conditions in table below.
4. Close pinch clamp before stopping engine.

To test crankcase vacuum with vacuum/pressure gauge:

1. Remove dipstick or oil fill plug/cap.
2. Install adapter into oil fill/dipstick tube opening, upside down over end of a small diameter dipstick tube, or directly into engine if a tube is not used. Insert barbed gauge fitting into hole in stopper.
3. Run engine and observe gauge reading.
Analog tester—needle movement to left of 0 is a vacuum, and movement to right indicates a pressure.
Digital tester—depress test button on top of tester.
Crankcase vacuum should be a minimum of 10.2 cm (4 in.) of water. If reading is below specification, or if pressure is present, check table below for possible causes and conclusions.

Condition	Conclusion
Crankcase breather clogged or inoperative.	<p>NOTE: If breather is integral part of valve cover and cannot be serviced separately, replace valve cover and recheck pressure.</p> <p>Disassemble breather, clean parts thoroughly, check sealing surfaces for flatness, reassemble, and recheck pressure.</p>
Seals and/or gaskets leaking. Loose or improperly torque fasteners.	Replace all worn or damaged seals and gaskets. Make sure all fasteners are tightened securely. Use appropriate torque valves and sequences when necessary.
Piston blow by or leaky valves (confirm by inspecting components).	Recondition piston, rings, cylinder bore, valves and valves guides.
Restricted exhaust.	Check exhaust screen/spark arrestor (if equipped). Clean or replace as needed. Repair or replace any other damaged/restricted muffler or exhaust system parts.

COMPRESSION TEST

For Command Twins:

A compression test is best performed on a warm engine. Clean any dirt or debris away from base of spark plug(s) before removing them. Be sure choke is off, and throttle is wide open during test. Compression should be at least 160 psi and should not vary more than 15% between cylinders.

All other models:

These engines are equipped with an automatic compression release (ACR) mechanism. It is difficult to obtain an accurate compression reading because of ACR mechanism. As an alternative, use cylinder leakdown test described below.

CYLINDER LEAKDOWN TEST

A cylinder leakdown test can be a valuable alternative to a compression test. By pressurizing combustion chamber from an external air source you can determine if valves or rings are leaking, and how badly.

Cylinder leakdown tester is a relatively simple, inexpensive leakdown tester for small engines. This tester includes a quick-connect for attaching adapter hose and a holding tool.

1. Run engine for 3-5 minutes to warm it up.
2. Remove spark plug(s) and air filter from engine.
3. Rotate crankshaft until piston (of cylinder being tested) is at top dead center (TDC) of compression stroke. Hold engine in this position while testing. Holding tool supplied with tester can be used if PTO end of crankshaft is accessible. Lock holding tool onto crankshaft. Install a 3/8 in. breaker bar into hole/slot of holding tool, so it is perpendicular to both holding tool and crankshaft PTO.

If flywheel end is more accessible, use a breaker bar and socket on flywheel nut/screw to hold it in position. An assistant may be needed to hold breaker bar during testing. If engine is mounted in a piece of equipment, it may be possible to hold it by clamping or wedging a driven component. Just be certain that engine cannot rotate off of TDC in either direction.

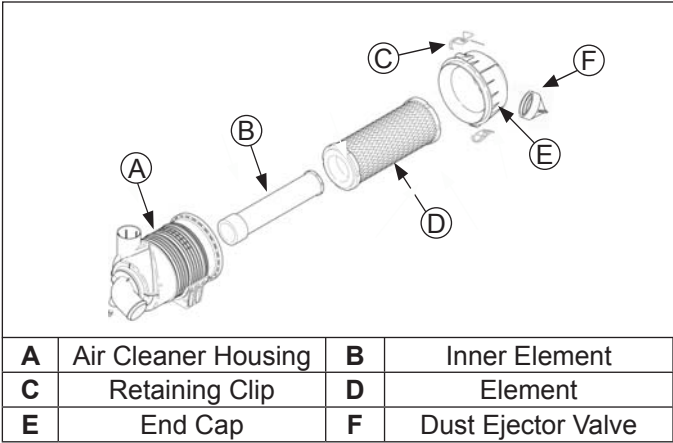
4. Install adapter into spark plug hole, but do not attach it to tester at this time.
5. Turn regulator knob completely counterclockwise.
6. Connect an air source of at least 50 psi to tester.
7. Turn regulator knob clockwise (increase direction) until gauge needle is in yellow set area at low end of scale.
8. Connect tester quick-connect to adapter hose. While firmly holding engine at TDC, gradually open tester valve. Note gauge reading and listen for escaping air at combustion air intake, exhaust outlet, and crankcase breather.

Condition	Conclusion
Air escaping from crankcase breather.	Ring or cylinder worn.
Air escaping from exhaust system.	Defective exhaust valve/improper seating.
Air escaping from intake.	Defective intake valve/improper seating.
Gauge reading in low (green) zone.	Piston rings and cylinder in good condition.
Gauge reading in moderate (yellow) zone.	Engine is still usable, but there is some wear present. Customer should start planning for overhaul or replacement.
Gauge reading in high (red) zone.	Rings and/or cylinder have considerable wear. Engine should be reconditioned or replaced.

Air Cleaner/Intake

AIR CLEANER

These systems are CARB/EPA certified and components should not be altered or modified in any way.



NOTE: Operating engine with loose or damaged air cleaner components could cause premature wear and failure. Replace all bent or damaged components.

NOTE: Paper element cannot be blown out with compressed air.

1. Unhook retaining clips and remove end cap(s).
2. Check and clean inlet screen (if equipped).
3. Pull air cleaner element out of housing and replace. Check condition of inner element; replace when dirty.
4. Check all parts for wear, cracks, or damage, and that ejector area is clean.
5. Install new element(s).
6. Reinstall end cap(s) with dust ejector valve/screen down; secure with retaining clips.

BREATHER TUBE


Ensure both ends of breather tube are properly connected.

AIR COOLING

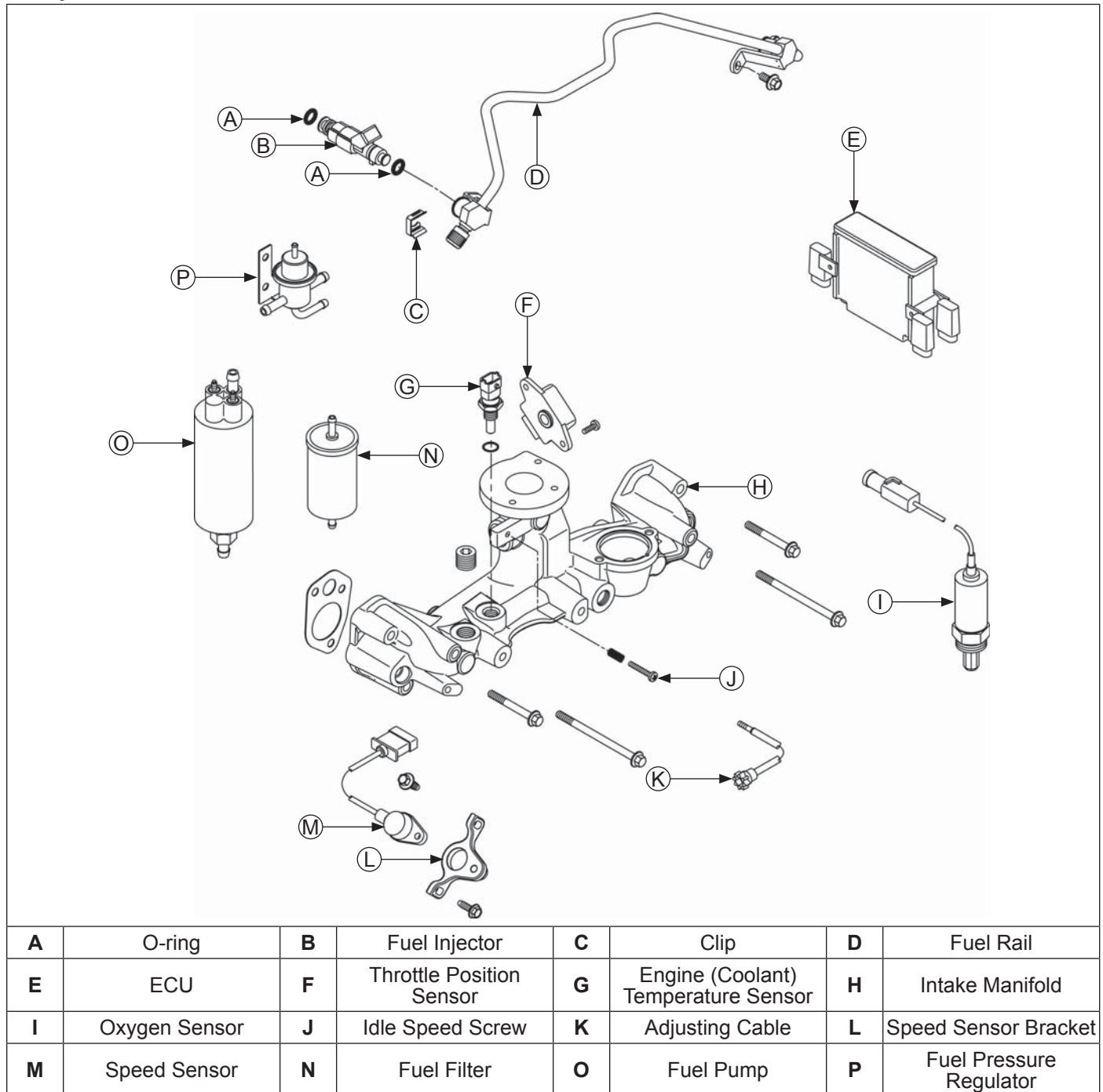
	! WARNING
	Hot Parts can cause severe burns. Do not touch engine while operating or just after stopping.
	Never operate engine with heat shields or guards removed.

NOTE: Operating engine with a restricted air intake screen or radiator, damaged/ broken fan assembly, or missing fan shroud will cause engine damage due to over heating.

Proper cooling is essential. To prevent over heating, clean screens, cooling fins, and other external surfaces of engine. Avoid spraying water at wiring harness or any electrical components. See Maintenance Schedule.

	⚠ WARNING	Gasoline is extremely flammable and its vapors can explode if ignited. Store gasoline only in approved containers, in well ventilated, unoccupied buildings, away from sparks or flames. Spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Never use gasoline as a cleaning agent.
	Explosive Fuel can cause fires and severe burns. Do not fill fuel tank while engine is hot or running.	

EFI System



EFI System

Typical electronic fuel injection (EFI) system and related components include:

- Fuel tank and valve.
- Fuel pump.
- Fuel filter.
- Fuel rail.
- Fuel line(s).
- Fuel injectors.
- Fuel pressure regulator.
- Throttle body/intake manifold.
- Electronic control unit (ECU).
- Ignition coils.
- Engine (oil) temperature sensor.
- Throttle position sensor (TPS).
- Speed sensor.
- Crankshaft position sensor.
- Oxygen sensor.
- Wire harness assembly & affiliated wiring.
- Malfunction indicator light (MIL).
- Intake air temperature sensor.

FUEL RECOMMENDATIONS

Refer to Maintenance.

FUEL LINE

Low permeation fuel line must be installed on all Kohler Co. engines to maintain EPA and CARB regulatory compliance.

OPERATION

NOTE: When performing voltage or continuity tests, avoid putting excessive pressure on or against connector pins. Flat pin probes are recommended for testing to avoid spreading or bending terminals.

EFI system is designed to provide peak engine performance with optimum fuel efficiency and lowest possible emissions. Ignition and injection functions are electronically controlled, monitored and continually corrected during operation to maintain ideal air/fuel ratio.

Central component of system is Engine Control Unit (ECU) which manages system operation, determining best combination of fuel mixture and ignition timing for current operating conditions.

An electric fuel pump is used to move fuel from tank through fuel line and in-line fuel filter. A fuel pressure regulator maintains a system operating pressure of 39 psi and returns any excess fuel to tank. At engine, fuel is fed through fuel rail and into injectors, which inject it into intake ports. ECU controls amount of fuel by varying length of time that injectors are ON. This can range from 1.5-8.0 milliseconds depending on fuel requirements. Controlled injection of fuel occurs each crankshaft revolution, or twice for each 4-stroke cycle. One-half total amount of fuel needed for one firing of a cylinder is injected during each injection. When intake valve opens, fuel/air mixture is drawn into combustion chamber, ignited, and burned.

ECU controls amount of fuel being injected and ignition timing by monitoring primary sensor signals for engine temperature, speed (RPM), and throttle position (load). These primary signals are compared to preprogrammed maps in ECU computer chip, and ECU adjusts fuel delivery to match mapped values. After engine reaches operating temperature, an exhaust gas oxygen sensor provides feedback to ECU based upon amount of unused oxygen in exhaust, indicating whether fuel mixture being delivered is rich or lean. Based upon this feedback, ECU further adjusts fuel input to re-establish ideal air/fuel ratio. This operating mode is referred to as closed loop operation. EFI system operates closed loop when all three of following conditions are met:

- Oil temperature is greater than 35°C (95°F).
- Oxygen sensor has warmed sufficiently to provide a signal (minimum 375°C, 709°F).
- Engine operation is at a steady state (not starting, warming up, accelerating, etc.).

During closed loop operation ECU has ability to readjust temporary and learned adaptive controls, providing compensation for changes in overall engine condition and operating environment, so it will be able to maintain ideal air/fuel ratio. This system requires a minimum engine oil temperature greater than 80°C (176°F) to properly adapt. These adaptive values are maintained as long as ECU is not reset.

During certain operating periods such as cold starts, warm up, acceleration, etc., an air/fuel ratio richer than 14.7:1 is required and system operates in an open loop mode. In open loop operation oxygen sensor output is not used, and controlling adjustments are based on primary sensor signals and programmed maps only. System operates open loop whenever three conditions for closed loop operation (above) are not being met.

ECU is a brain or central processing computer of entire EFI fuel/ignition management system. During operation, sensors continuously gather data which is relayed through wiring harness to input circuits within ECU. Signals to ECU include: ignition (on/off), crankshaft position and speed (RPM), throttle position, oil temperature, exhaust oxygen levels, and battery voltage. ECU compares input signals to programmed maps in its memory to determine appropriate fuel and spark requirements for immediate operating conditions. ECU then sends output signals to set injector duration and ignition timing.

ECU compares input signals to programmed maps in its memory to determine appropriate fuel and spark requirements for immediate operating conditions. ECU then sends output signals to set injector duration and ignition timing.

ECU continually performs a diagnostic check of itself, each of sensors, and system performance. If a fault is detected, ECU can turn on a Malfunction Indicator Light (MIL) (if equipped) on equipment control panel, store fault code in its fault memory, and go into a default operating mode. Depending on significance or severity of fault, normal operation may continue. A technician can access stored fault code using a blink code diagnosis flashed out through MIL. An optional computer software diagnostic program is also available, see Tools and Aids.

ECU requires a minimum of 7.0 volts to operate. Adaptive memory in ECU is operational whenever required voltage is present, however adapted values are lost if power supply is disrupted for any reason. ECU will relearn adapted values if engine is operated for 10-15 minutes at varying speeds and loads after oil temperature exceeds 55°C (130°F).

To prevent engine over-speed and possible failure, a rev-limiting feature is programmed into ECU. If maximum RPM limit (4500) is exceeded, ECU suppresses injection signals, cutting off fuel flow. This process repeats itself in rapid succession, limiting operation to preset maximum.

Engine speed sensor is essential to engine operation; constantly monitoring rotational speed (RPM) of crankshaft. A ferromagnetic 60-tooth ring gear with two consecutive teeth missing is mounted on flywheel. Inductive speed sensor is mounted 1.5 ± 0.25 mm (0.059 ± 0.010 in.) away from ring gear. During rotation, an AC voltage pulse is created within sensor for each passing tooth. ECU calculates engine speed from time interval between consecutive pulses. Two-tooth gap creates an interrupted input signal, corresponding to specific crankshaft position (84° BTDC) for cylinder #1. This signal serves as a reference for control of ignition timing by ECU. Synchronization of inductive speed pickup and crankshaft position takes place during first two revolutions each time engine is started. Sensor must be properly connected at all times. If sensor becomes disconnected for any reason, engine will quit running.

Throttle position sensor (TPS) is used to indicate throttle plate angle to ECU. Since throttle (by way of governor) reacts to engine load, angle of throttle plate is directly related to load on engine.

Mounted on throttle body/intake manifold and operated directly off end of throttle shaft, TPS works as a potentiometer, varying voltage signal to ECU in direct correlation to angle of throttle plate. This signal, along with other sensor signals, is processed by ECU and compared to internal pre-programmed maps to determine required fuel and ignition settings for amount of load.

Correct position of TPS is established and set at factory. Do not loosen TPS or alter mounting position unless absolutely required by fault code diagnosis or throttle shaft service. If TPS is loosened or repositioned, appropriate TPS Initialization Procedure must be performed to reestablish baseline relationship between ECU and TPS.

Engine (oil) temperature sensor is used by system to help determine fuel requirements for starting (a cold engine needs more fuel than one at or near operating temperature).

Mounted in oil filter adapter housing, it has a temperature-sensitive resistor that extends into oil flow. Resistance changes with oil temperature, altering voltage sent to ECU. Using a table stored in its memory, ECU correlates voltage drop to a specific temperature. Using fuel delivery maps, ECU then knows how much fuel is required for starting at that temperature.

Oxygen sensor functions like a small battery, generating a voltage signal to ECU based upon difference in oxygen content between exhaust gas and ambient air.

Tip of sensor, protruding into exhaust gas, is hollow. Outer portion of tip is surrounded by exhaust gas, with inner portion exposed to ambient air. When oxygen concentration on one side of tip is different than that of other side, a voltage signal between 0.2 and 1.0 volts is generated between electrodes and sent to ECU. Voltage signal tells ECU if engine is straying from ideal 14.7:1 fuel mixture, and ECU then adjusts injector pulse accordingly.

Oxygen sensor can function only after being heated by exhaust temperatures to a minimum of 375°C (709°F). A cold oxygen sensor will require approximately 1-2 minutes at moderate engine load to warm sufficiently to generate a voltage signal. Proper grounding is also critical. Oxygen sensor grounds through metal shell, so a good, solid, unbroken ground path back through exhaust system components, engine, and wiring harness is required. Any disruption or break in ground circuit can affect output signal and trigger misleading fault codes. Keep that in mind when doing any troubleshooting associated with oxygen sensor. Oxygen sensor can also be contaminated by leaded fuel, certain RTV and/or other silicone compounds, carburetor cleaners, etc. Use only those products indicated as O₂ Sensor Safe.

Electrical relay is used to supply power to injectors, coil, and fuel pump. When key switch is turned ON and all safety switch requirements met, relay provides 12 volts to fuel pump circuit, injectors, and ignition coils. Fuel pump circuit is continuously grounded, so pump is immediately activated and pressurizes system. Activation of ignition coils and fuel injectors is controlled by ECU, which grounds their respective ground circuits at proper times.

Fuel injectors mount into throttle body/intake manifold, and fuel rail attaches to them at top end. Replaceable O-rings on both ends of injector prevent external fuel leakage and also insulate it from heat and vibration. A special clip connects each injector to fuel rail and holds it in place. O-rings must be replaced anytime injector is removed.

When key switch is on and relay is closed, fuel rail is pressurized, and voltage is present at injector. At proper instant, ECU completes ground circuit, energizing injector. Valve needle in injector is opened electromagnetically, and pressure in fuel rail forces fuel down through inside. Director plate at tip of injector contains a series of calibrated openings which directs fuel into manifold in a cone-shaped spray pattern.

Injector is opened and closed once for each crankshaft revolution, however only one-half total amount of fuel needed for one firing is injected during each opening. Amount of fuel injected is controlled by ECU and determined by length of time valve needle is held open, also referred to as injection duration or pulse width. It may vary in length from 1.5-8 milliseconds depending on speed and load requirements of engine.

EFI System

A high-voltage, solid-state, battery ignition system is used with EFI system. ECU controls ignition output and timing through transistorized control of primary current delivered to coils. Based on input from speed sensor, ECU determines correct firing point for speed at which engine is running. At proper instant, it releases flow of primary current to coil. Primary current induces high voltage in coil secondary, which is then delivered to spark plug. Each coil fires every revolution, but every other spark is wasted.

An electric fuel pump is used to transfer fuel in EFI system. Depending on application, pump may be inside fuel tank, or in fuel line near tank. Pumps are rated for a minimum output of 25 liters per hour at 39 psi. Pumps have an internal 60-micron filter. In addition, in-tank style pumps will have a pre-filter attached to inlet. In-line pump systems may also have a filter between tank and pump on pickup/low pressure side.

When key switch is turned ON and all safety switch requirements are met, ECU, through relay activates fuel pump, which pressurizes system for start-up. If key switch is not promptly turned to start position, engine fails to start, or engine is stopped with key switch ON (as in case of an accident), ECU switches off pump preventing continued delivery of fuel. In this situation, MIL will go on, but it will go back off after 4 cranking revolutions if system function is OK. Once engine is running, fuel pump remains on.

Fuel pressure regulator assembly maintains required operating system pressure of 39 psi \pm 3. A rubber-fiber diaphragm divides regulator into two separate sections; fuel chamber and pressure regulating chamber. Pressure regulating spring presses against valve holder (part of diaphragm), pressing valve against valve seat. Combination of atmospheric pressure and regulating spring tension equals desired operating pressure. Any time fuel pressure against bottom of diaphragm exceeds desired (top) pressure, valve opens, relieving excess pressure, returning excess fuel back to tank.

Fuel rail is a formed tube assembly that feeds fuel to top of injectors. Tops of injectors fit into formed cups in fuel rail. When rail is fastened to manifold, injectors are locked into place. A small retaining clip provides a secondary lock. Incorporated into fuel rail is a pressure relief/test valve for testing operating pressure or relieving fuel system pressure for servicing. Fuel supply line is attached to barbed end of fuel rail with an Oetiker hose clamp.

EFI engines have no carburetor, so throttle function (regulate incoming combustion airflow) is incorporated in intake manifold assembly. Manifold consists of a one-piece aluminum casting which also provides mounting for fuel injectors, throttle position sensor, fuel rail, air baffle, idle speed screw, and air cleaner assembly.

Idle speed is only adjustment that may be performed on EFI system. Standard idle speed setting for EFI engines is 1500 RPM, but certain applications might require a different setting. Check equipment manufacturer's recommendation.

For starting and warm up, ECU will adjust fuel and ignition timing, based upon ambient temperature, engine temperature, and loads present. In cold conditions, idle speed will probably be higher than normal for a few moments. Under other conditions, idle speed may actually start lower than normal, but gradually increase to established setting as operation continues. Do not attempt to circumvent this warm up period, or readjust idle speed during this time. Engine must be completely warmed up, in closed loop operating mode for accurate idle adjustment.

IMPORTANT NOTES!

- Cleanliness is essential and must be maintained at all times when servicing or working on EFI system. Dirt, even in small quantities, can cause significant problems.
- Clean any joint or fitting with parts cleaning solvent before opening to prevent dirt from entering system.
- Always depressurize fuel system through fuel connector on fuel pump module before disconnecting or servicing any fuel system components.
- Never attempt to service any fuel system component while engine is running or ignition switch is ON.
- Do not use compressed air if system is open. Cover any parts removed and wrap any open joints with plastic if they will remain open for any length of time. New parts should be removed from their protective packaging just prior to installation.
- Avoid direct water or spray contact with system components.
- Do not disconnect or reconnect ECU wiring harness connector or any individual components with ignition on. This can send a damaging voltage spike through ECU.
- Do not allow battery cables to touch opposing terminals. When connecting battery cables attach positive (+) cable to positive (+) battery terminal first, followed by negative (–) cable to negative (–) battery terminal.
- Never start engine when cables are loose or poorly connected to battery terminals.
- Never disconnect battery while engine is running.
- Never use a quick battery charger to start engine.
- Do not charge battery with key switch ON.
- Always disconnect negative (–) battery cable before charging battery, and also unplug harness from ECU before performing any welding on equipment.

Initial Starting/Priming Procedure

Important: EFI fuel system must be purged of air (primed) prior to initial start up, and/or any time system has been disassembled or fuel tank run dry.

1. Locate electronic control unit (ECU) for EFI system. Check part number on end. If Part No. is 24 584 28 or higher, ECU has a built-in priming feature.
 - a. Turn key switch to ON/RUN position. You will hear fuel pump cycle on and off. When fuel pump stops cycling (approximately one minute), system is primed; start engine.
2. For plastic-cased ECU's below 24 584 28-S, system can be primed by manually cycling fuel pump.

- a. Turn key switch to ON/RUN position. Fuel pump will run for about three seconds and stop. Turn switch off and back on to restart fuel pump. Repeat this procedure until fuel pump has cycled five times, then start engine.
3. System can also be primed similar to relieving pressure.
 - a. Connect pressure gauge as described above for relieving fuel pressure. Depress and hold release button and crank engine until air is purged and fuel is visible in discharge tube. If fuel is not visible after 10 seconds, stop cranking and allow starter to cool for 60 seconds.

Priming Without a Test Valve in Fuel Rail

NOTE: Number of cranking intervals necessary will depend on individual system design, and/or when system has been disassembled.

1. Crank engine in 10-15 second intervals, allowing a 60 second cool-down period between cranking intervals, until engine starts.

ELECTRICAL COMPONENTS

A 32 pin (MSE 1.1) plastic-cased ECU is used on these engines.

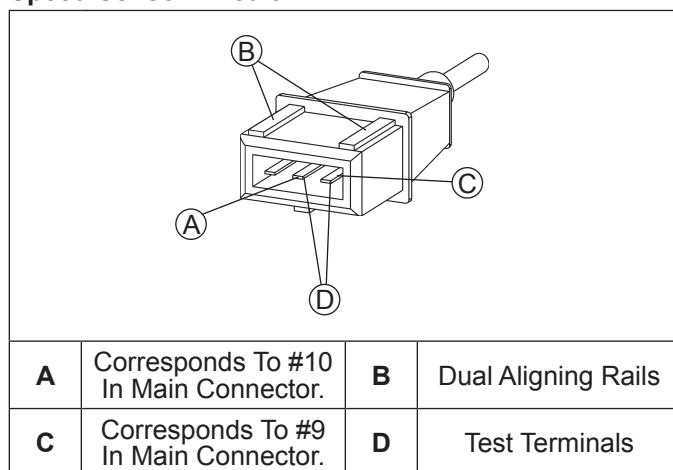
Never attempt to disassemble ECU. It is sealed to prevent damage to internal components. Warranty is void if case is opened or tampered with in any way.

All operating and control functions within ECU are preset. No internal servicing or readjustment may be performed. If a problem is encountered, and you determine ECU to be faulty, contact your source of supply. Do not replace ECU without factory authorization.

Relationship between ECU and throttle position sensor (TPS) is very critical to proper system operation. If TPS or ECU is changed, or mounting position of TPS is altered, applicable TPS Initialization Procedure must be performed to restore synchronization.

ENGINE SPEED SENSOR

Speed Sensor Circuit



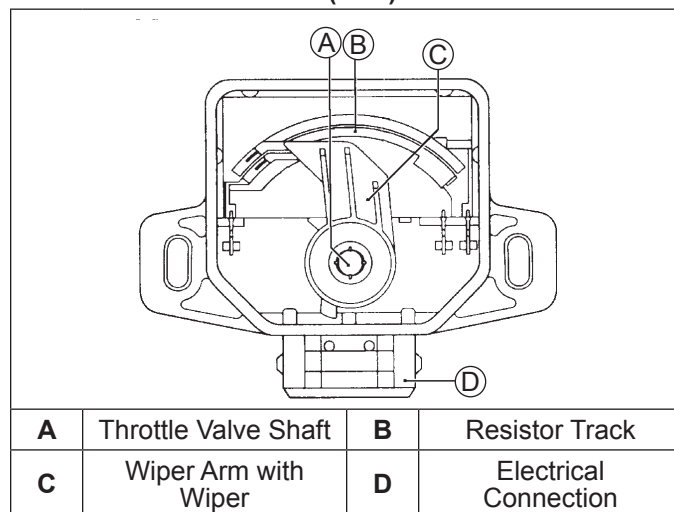
Engine speed sensor is a sealed, non-serviceable assembly. If Fault Code diagnosis indicates a problem within this area, check and test as follows.

1. Check mounting and air gap of sensor. It must be 1.5 mm \pm 0.25 mm (0.059 in. \pm 0.010 in.).
2. Inspect wiring and connections for damage or problems.
3. Make sure engine has resistor type spark plugs.
4. Disconnect main harness connector from ECU.
5. Connect an ohmmeter between #9 and #10 pin terminals.

A resistance value of 750-1000 Ω at room temperature (20°C, 68°F) should be obtained. If resistance is correct, check mounting, air gap, toothed ring gear (damage, runout, etc.), and flywheel key.

6. Disconnect speed sensor connector from wiring harness. It is connector with one heavy black lead. Viewing connector as shown (dual aligning rails on top), test resistance between terminals indicated. A reading of 750-1000 Ω should again be obtained.
7. If resistance is incorrect, remove screw securing sensor to mounting bracket and replace sensor.
 - a. If resistance in step 5 was incorrect, but resistance of sensor alone was correct, test main harness circuits between sensor connector terminals and corresponding pin terminals in main connector. Correct any observed problem, reconnect sensor, and perform step 5 again.

Throttle Position Sensor (TPS)



TPS is a sealed, non-serviceable assembly. If diagnosis indicates a bad sensor, complete replacement is necessary. If a blink code indicates a problem with TPS, it can be tested as follows:

1. Counting number of turns, back out idle speed adjusting screw (counterclockwise) until throttle plates can be closed completely.
2. Disconnect main harness connector from ECU, but leave TPS mounted to throttle body/manifold.
3. Connect Red (positive) ohmmeter lead to #8 pin terminal, and Black (negative) ohmmeter lead to #4 pin terminal. Hold throttle closed and check resistance. It should be 800-1200 Ω .

EFI System

4. Leave leads connected to pin terminals as described in step 3. Rotate throttle shaft slowly counterclockwise to full throttle position. Monitor dial during rotation for indication of any momentary short or open circuits. Note resistance at full throttle position. It should be 1800-3000 Ω .
5. Disconnect main wiring harness connector from TPS, leaving TPS assembled to manifold. Refer to chart below and perform resistance checks indicated between terminals in TPS switch, with throttle in positions specified.

Throttle Position	Between Terminals	Resistance Value (Ω)	Continuity
Closed	2 & 3	800-1200	Yes
Closed	1 & 3	1800-3000	Yes
Full	2 & 3	1800-3000	Yes
Full	1 & 3	800-1200	Yes
Any	1 & 2	1600-2500	Yes

If resistance values in steps 3, 4, and 5 are within specifications, go to step 6.

If resistance values are not within specifications, or a momentary short or open circuit was detected during rotation (step 4), TPS needs to be replaced, go to step 7.

6. Check TPS circuits (input, ground) between TPS plug and main harness connector for continuity, damage, etc., Circuits #8 and #4.
 - a. Repair or replace as required.
 - b. Turn idle speed screw back in to its original setting.
 - c. Reconnect connector plugs, start engine and retest system operation.
7. Remove two mounting screws from TPS. Save screws for reuse. Remove and discard faulty TPS. Install replacement TPS and secure with original mounting screws.
 - a. Reconnect both connector plugs.
 - b. Perform appropriate TPS Initialization Procedure integrating new sensor to ECU.

TPS Initialization Procedure

1. Check that basic engine, all sensors, fuel, fuel pressure, and battery are good and functionally within specifications.

Important!

2. Remove/disconnect ALL external loads from engine (belts, pumps, electric PTO clutch, alternator, rectifier-regulator, etc.).
3. Locate service connector plug in wiring harness. To initiate TPS auto-learn function, connect a jumper wire from TPS initialization pin #24 (violet wire) to battery voltage pin (red wire), or use jumper plug with blue jumper wire. If using PC-based diagnostic tool and software, refer to Special Tests in Tools/Aids and follow prompts to complete.
4. Start engine and immediately observe Malfunction Indicator Light (MIL). Light should start blinking 4 consecutive times every 2 seconds.

5. Remove jumper wire or plug from service connector plug in wiring harness.
6. Run engine at full throttle (above 3000 RPM), to warm up engine and initiate O₂ sensor function in closed-loop operation.
7. Watch MIL. When light starts blinking rapidly, (5 blinks per second), move throttle lever to low idle speed position. Check and adjust idle speed to 1500 RPM, using a tachometer. Lamp should continue to blink rapidly for another 30 seconds before switching to a slow blink.
8. When MIL blinks slowly, do not do anything but wait until MIL shuts off. This indicates that this procedure has been completed successfully.
9. Shut off engine.

If learn procedure was successfully completed, external loads removed/disconnected in Step 2 may be reconnected.

If procedure was unsuccessful see Steps a. and b. following.

- a. If during this procedure, MIL goes back into blinking 4 consecutive blinks every 2 seconds, engine and O₂ sensor have cooled down and out of closed-loop operation, prohibiting learning from occurring. Repeat Steps 6-9.
- b. If during procedure with engine running, MIL stays ON continuously, for more than 15 seconds, turn off ignition. Then initiate fault code sequence, by doing three consecutive key-on/key-off cycles leaving key ON in last sequence, (each key-on/key-off sequence must be less than 2.5 seconds long). Fault detected must be corrected before auto-learn function can be re-initiated. PC-based diagnostic tool and software may be used to read out fault code and assist with troubleshooting and repair.

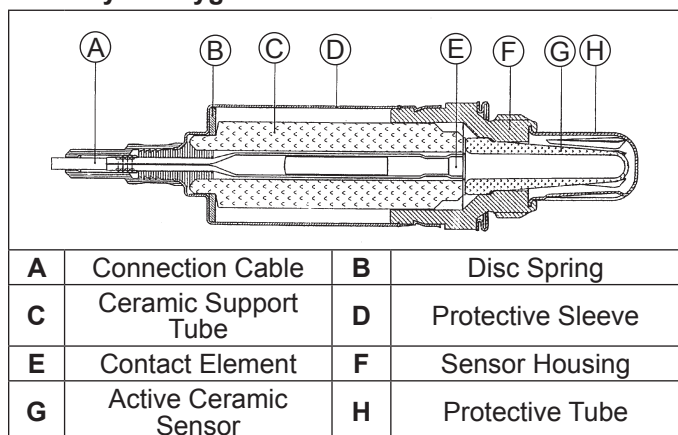
ENGINE (COOLANT) TEMPERATURE SENSOR

Temperature sensor is a sealed, non-serviceable assembly. A faulty sensor must be replaced. If a blink code indicates a problem with temperature sensor, it can be tested as follows:

1. Remove oil temperature sensor from adapter housing and cap or block adapter hole.
2. Wipe sensor clean and allow it to reach room temperature (20°C, 68°F).
3. Unplug main harness connector from ECU.
4. With sensor connected, check oil temperature sensor circuit resistance. Check between #6 and #4 pin terminals. Value should be 2375-2625 Ω .
5. Unplug sensor connector and check sensor resistance separately. Resistance value should again be 2375-2625 Ω .
 - a. If resistance is out of specifications, replace temperature sensor.
 - b. If it is within specifications, proceed to Step 6.
6. Check temperature sensor circuits (input, ground) from main harness connector to corresponding terminal in sensor plug for continuity, damage, etc. Pin circuits #6 and #4.

OXYGEN SENSOR

Cutaway of Oxygen Sensor



NOTE: All tests should be conducted with a good quality, high-impedance, digital VOA meter for accurate results.

Like other sensors already discussed, oxygen sensor is a non-serviceable component. Complete replacement is required if it is faulty. Sensor and wiring harness can be checked as follows.

1. Oxygen sensor must be hot (minimum of 400°C, 752°F). Run engine for about 5 minutes. With engine running, disconnect oxygen sensor lead from wiring harness. Set VOA meter for DC volts and connect red lead to disconnected sensor lead, and black lead to sensor shell. Look for a voltage reading from 0.2 v-1.0 v.
 - a. If voltage is in specified range, go to Step 2.
 - b. If voltage is not in specified range, reconnect oxygen sensor lead. With lead connected, probe or connect sensor connection with red VOA meter lead. Attach black VOA meter lead to a good ground location. Start and run engine at 3/4 throttle and note voltage reading being signaled by oxygen sensor. Reading should cycle between 0.2 v and 1.0 v, which indicates oxygen sensor is functioning normally and fuel delivery is within prescribed parameters. If voltage readings show a steady decline, rev engine and check indicated reading again. If voltage momentarily increases and then again declines, without cycling, engine may be running lean due to incorrect TPS initialization. Shut off engine, perform TPS initialization, and then repeat test. If TPS initialization cannot be achieved, perform step c.
 - c. Replace oxygen sensor (see next page). Run engine long enough to bring new sensor up to temperature and repeat output test from step 1. Cycling voltage from 0.2 to 1.0 v should be indicated.
2. Move black voltmeter lead to engine ground location and repeat output test. Same voltage (0.2 v-1.0 v) should be indicated.
 - a. If same voltage reading exists, go on to Step 3.

- b. If voltage output is no longer correct, a bad ground path exists between sensor and engine ground. Touch black lead at various points, backtracking from engine ground back toward sensor, watching for a voltage change at each location. If correct voltage reading reappears at some point, check for a problem (rust, corrosion, loose joint or connection) between that point and previous checkpoint. For example, if reading is too low at points on crankcase, but correct voltage is indicated when black lead is touched to skin of muffler, flange joints at exhaust ports become suspect.
3. With sensor still hot (minimum of 400°C, 752°F), switch meter to Rx1K or Rx2K scale and check resistance between sensor lead and sensor case. It should be less than 2.0 KΩ.
 - a. If resistance is less than 2.0 KΩ go to Step 4.
 - b. If resistance is greater than 2.0 KΩ, oxygen sensor is bad, replace it.
4. Allow sensor to cool (less than 60°C, 140°F) and retest resistance with meter set on Rx1M scale. With sensor cool, resistance should be greater than 1.0 MΩ.
 - a. If resistance is greater than 1.0 MΩ go to Step 5.
 - b. If resistance is less than 1.0 MΩ, sensor is bad, replace it.
5. With oxygen sensor disconnected and engine not running, disconnect main harness connector from ECU and set meter to Rx1 scale. Check for continuity from pin #19 of ECU connector to shell of oxygen sensor, and from pin #20 to sensor terminal of main harness. Both tests should indicate continuity.
 - a. If there is no continuity displayed in either of tests, check harness circuit for breaks or damage, and connections for poor contact, moisture, or corrosion. If no continuity was found in first test, also check for a poor/broken ground path back through exhaust system, engine, and mounting (sensor is grounded through its shell).
 - b. If continuity is indicated, go to step 6.
6. With key switch in ON/RUN position, using a high impedance voltmeter, check voltage from wiring harness oxygen sensor connector to engine ground location. Look for a steady voltage from 350-550 mv (0.35-0.55 v).
 - a. If voltage reading is not as specified, move black voltmeter lead to negative post of battery, to be certain of a good ground. If voltage is still not correct, ECU is probably bad.
 - b. If voltage readings are correct, clear fault codes and run engine to check if any fault codes reappear.

To Replace Oxygen Sensor

1. Disconnect oxygen sensor connector from wiring harness.
2. Loosen and remove oxygen sensor from exhaust manifold/muffler assembly.

EFI System

3. Apply anti-seize compound sparingly to threads of new oxygen sensor, if none already exists. DO NOT get any on tip as it will contaminate sensor. Install sensor and torque to 50-60 N·m (37-44 ft. lb.).
4. Reconnect lead to wiring harness connector. Make sure it can not contact hot surfaces, moving parts, etc.
5. Test run engine.

ELECTRICAL RELAY

A malfunctioning relay can result in starting or operating difficulties. Relay and related wiring can be tested as follows:

1. Disconnect relay connector plug from relay.
2. Connect black lead of VOA meter to a chassis ground location. Connect red lead to #86 terminal in relay connector. Set meter to test resistance (Rx1). Turn ignition switch from OFF to ON. Meter should indicate continuity (ground circuit is completed) for 1 to 3 seconds. Turn key switch back off.
 - a. Clean connection and check wiring if circuit was not completed.
3. Set meter for DC voltage. Touch red tester lead to #30 terminal in relay connector. A reading of 12 volts should be indicated at all times.
4. Connect red lead of meter to #85 terminal in relay connector. Turn key switch to ON position. Battery voltage should be present.
 - a. No voltage present indicates a problem with key switch, in wiring, or at connector.
 - b. If voltage is present, wiring to connector is good. Turn ignition switch OFF and proceed to Step 5 to test relay.
5. Connect an ohmmeter (Rx1 scale) between #85 and #86 terminals in relay. There should be continuity.
6. Attach ohmmeter leads to #30 and #87 terminals in relay. First, there should be no continuity. Using a 12 volt power supply, connect positive (+) lead to #85 terminal and touch negative (–) lead to #86 terminal. When 12 volts is applied, relay should activate and continuity should exist between #30 and #87 terminals. Repeat test several times. If, at any time relay fails to activate circuit, replace relay.

Electrical relay is used to supply power to injectors, coils, and fuel pump. When key switch is turned ON and all safety switch requirements met, relay provides 12 volts to fuel pump circuit, injectors, and ignition coils. fuel pump circuit is continuously grounded, so pump is immediately activated and pressurizes system. Activation of ignition coils and injectors is controlled by ECU, which grounds their respective circuits at proper times.

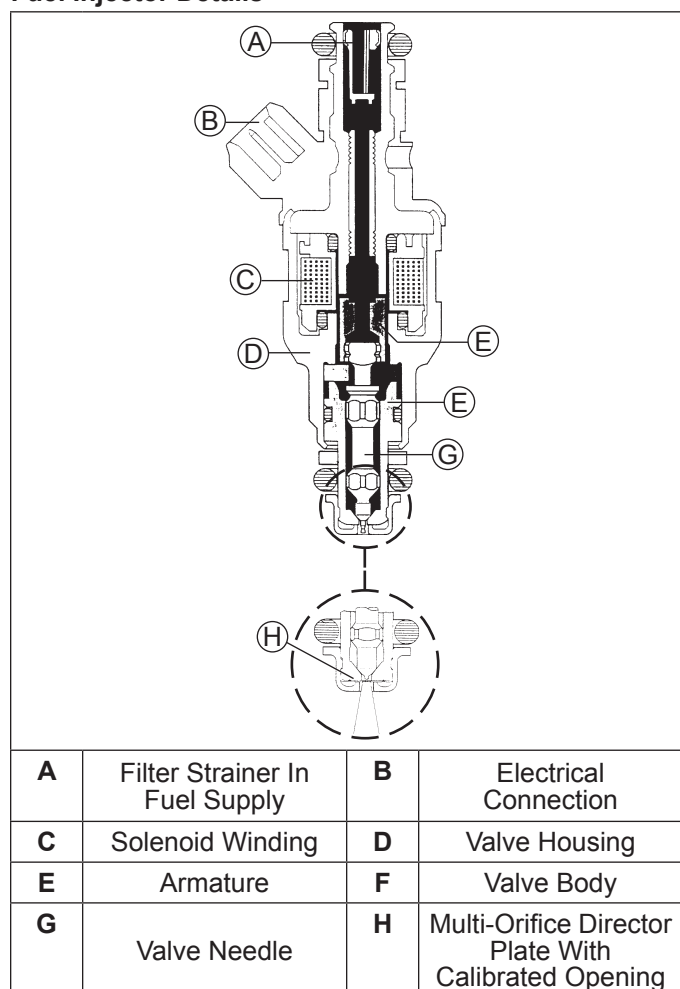
Service

A malfunctioning relay can result in starting or operating difficulties. relay and related wiring can be tested as follows.

1. Disconnect relay connector plug from relay.
2. Connect black lead of a VOA meter to a chassis ground location. Connect red lead to #86 terminal in relay connector. Set meter to test resistance (Rx1). Turn key switch from OFF to ON. Meter should indicate continuity (ground circuit is completed) for 1 to 3 seconds. Turn key switch back off.
 - a. Clean connection and check wiring if circuit was not completed.
3. Set meter for DC voltage. Touch red tester lead to #30 terminal in relay connector. A reading of 12 volts should be indicated at all times.
4. Connect red lead of meter to #85 terminal in relay connector. Turn key switch to ON position. Battery voltage should be present.
 - a. No voltage present indicates a problem in wiring or at connector.
 - b. If voltage is present, wiring to connector is good. Turn ignition switch OFF and proceed to test 5 to test relay.
5. Connect an ohmmeter (Rx1 scale) between #85 and #86 terminals in relay. There should be continuity.
6. Attach ohmmeter leads to #30 and #87 terminals in relay. Initially, there should be no continuity. Using a 12 volt power supply, connect positive (+) lead to #85 terminal and touch negative (–) lead to #86 terminal. When 12 volts is applied, relay should activate and continuity should exist (circuit made) between #30 and #87 terminals. Repeat test several times. If, at any time relay fails to activate circuit, replace relay.

FUEL INJECTOR

Fuel Injector Details



NOTE: Do not apply voltage to fuel injector(s). Excessive voltage will burn out injector(s). Do not ground injector(s) with ignition ON. Injector(s) will open/turn on if relay is energized.

Injector problems typically fall into three general categories: electrical, dirty/clogged, or leakage. An electrical problem usually causes one or both of injectors to stop functioning. Several methods may be used to check if injectors are operating.

1. With engine running at idle, feel for operational vibration, indicating that they are opening and closing.
2. When temperatures prohibit touching, listen for a buzzing or clicking sound with a screwdriver or mechanic's stethoscope.
3. Disconnect electrical connector from an injector and listen for a change in idle performance (only running on one cylinder) or a change in injector noise or vibration.

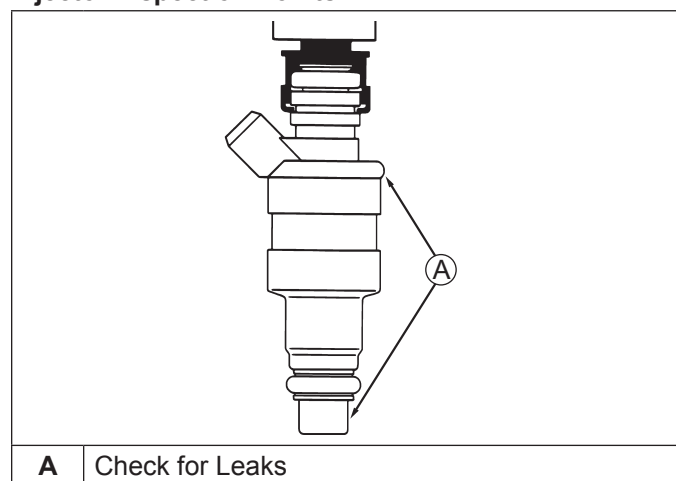
If an injector is not operating, it can indicate either a bad injector, or a wiring/electrical connection problem. Check as follows:

1. Disconnect electrical connector from both injectors. Plug a 12 volt noid light (part of EFI Service Kit) into one connector.

2. Make sure all safety switch requirements are met. Crank engine and check for flashing of test light. Repeat test at other connector.
 - a. If flashing occurs, use an ohmmeter (Rx1 scale) and check resistance of each injector across two terminals. Proper resistance is 12-20 Ω . If injector resistance is correct, check whether connector and injector terminals are making a good connection. If resistance is not correct, replace injector following steps 1-8 and 13-16 below.
 - b. If no flashing occurs, reattach connectors to both injectors. Disconnect main harness connector from ECU and connector from relay. Set ohmmeter to Rx1 scale and check injector circuit resistance between relay terminal #87 and pin #14 in main connector. Then check resistance between relay terminal #87 and pin #15. Resistance should be 4-15 Ω for each circuit. Check all electrical connections, connectors, and wiring harness leads if resistance is incorrect.

Injector leakage is very unlikely, but in those rare instances it can be internal (past tip of valve needle), or external (weeping around injector body). Loss of system pressure from leakage can cause hot restart problems and longer cranking times. To check for leakage it will be necessary to loosen or remove blower housing which may involve removing engine from unit.

Injector Inspection Points



1. Engine must be cool. Depressurize fuel system through test valve in fuel rail.
2. Disconnect spark plug leads from spark plugs.
3. Remove air cleaner outer cover, inner wing nut, element cover and air cleaner element/precleaner. Service air cleaner components as required.
4. Remove screws securing air cleaner base to throttle body manifold. Remove air cleaner base to permit access to injectors. Check condition of air cleaner base gasket, replace if necessary.
5. Remove flywheel screen if it overlaps blower housing.
6. If engine has a radiator-type oil cooler mounted to blower housing, remove oil cooler mounting screws.

EFI System

7. Remove blower housing mounting screws. Note location of plated (silver) screw attaching rectifier/regulator ground lead. Remove blower housing.
8. Thoroughly clean area around and including throttle body/manifold and injectors.
9. Disconnect throttle linkage and damper spring from throttle lever. Disconnect TPS lead from harness.
10. Remove manifold mounting bolts and separate throttle body/manifold from engine leaving TPS, fuel rail, air baffle, injectors and line connections intact. Discard old gaskets.
11. Position manifold assembly over an appropriate container and turn key switch ON to activate fuel pump and pressurize system. Do not turn switch to START position.
12. If either injector exhibits leakage of more than two to four drops per minute from tip, or shows any sign of leakage around outer shell, turn ignition switch off and replace injector as follows.
13. Depressurize fuel system following procedure in fuel warning on page. Remove fuel rail mounting screws.
14. Clean any dirt accumulation from sealing/mounting area of faulty injector(s) and disconnect electrical connector(s).
15. Pull retaining clip off top of injector(s). Disconnect fuel rail and remove injector(s) from manifold.
16. Reverse appropriate procedures to install new injector(s) and reassemble engine. Use new O-rings any time an injector is removed (new replacement injectors include new O-rings). Lubricate O-rings lightly with oil. Torque fuel rail and blower housing mounting screws to 3.9 N·m (35 in. lb.), and intake manifold and air cleaner mounting screws to 9.9 N·m (88 in. lb.).

Injector problems due to dirt or clogging are generally unlikely due to design of injectors, high fuel pressure, and detergent additives in gasoline. Symptoms that could be caused by dirty/clogged injectors include rough idle, hesitation/stumble during acceleration, or triggering of fault codes related to fuel delivery. Injector clogging is usually caused by a buildup of deposits on director plate, restricting flow of fuel, resulting in a poor spray pattern. Some contributing factors to injector clogging include higher than normal operating temperatures, short operating intervals, and dirty, incorrect, or poor quality fuel. Cleaning of clogged injectors is not recommended; they should be replaced. Additives and higher grades of fuel can be used as a preventative measure if clogging has been a problem.

NOTE: Do not ground coils with ignition ON, as they may overheat or spark.

IGNITION SYSTEM

A high voltage, solid state, battery ignition system is used with EFI system. ECU controls ignition output and timing through transistorized control of primary current delivered to coils. Based on input from speed sensor, ECU determines correct firing point for speed at which engine is running. At proper instant, it releases flow of primary current to coil. Primary current induces high voltage in coil secondary, which is then delivered to spark plug. Each coil fires every revolution, but every other spark is wasted.

Except for removing spark plug lead by unscrewing it from secondary tower, no coil servicing is possible. If a coil is determined to be faulty, replacement is necessary. An ohmmeter may be used to test wiring and coil windings.

Testing

1. Disconnect main harness connector from ECU. Locate pins #30 and #31 in 32 pin connector.
2. Disconnect connector from relay and locate terminal #87 in connector.
3. Using an ohmmeter set on Rx1 scale, check resistance between terminal #87 and pin #30 for coil #1. Repeat test between terminal #87 and pin #31 for coil #2.

A reading of 1.8-4.0 Ω in each test indicates that wiring and coil primary circuits are OK.

- a. If reading(s) are not within specified range, check and clean connections and retest.
- b. If reading(s) are still not within specified range, test coils separately from main harness as follows:

1. Disconnect red and black primary leads from coil terminals.
2. Connect an ohmmeter set on Rx1 scale to primary terminals. Primary resistance should be 1.8-2.5 Ω .
3. Disconnect secondary lead from spark plug. Connect an ohmmeter set on Rx10K scale between spark plug boot terminal and red primary terminal. Secondary resistance should be 13,000-17,500 Ω .
4. If secondary resistance is not within specified range, unscrew spark plug lead nut from coil secondary tower and remove plug lead. Repeat step b. 3, testing from secondary tower terminal to red primary terminal. If resistance is now correct, coil is good, but spark plug lead is faulty, replace lead. If step b. 2 resistance was incorrect and/or secondary resistance is still incorrect, coil is faulty and needs to be replaced.

Spark Plugs

EFI engines require resistor spark plugs. Do not try to substitute non-resistor plugs.

Wiring Harness

Wiring harness used in EFI system connects electrical components, providing current and ground paths for system to operate. All input and output signaling occurs through a special all weather connector that attaches and locks to ECU.

Condition of wiring, connectors, and terminal connections is essential to system function and performance. Corrosion, moisture, and poor connections are more likely cause of operating problems and system errors than an actual component.

Battery Charging System

EFI engines are equipped with either a 15 or 25 amp charging system to accommodate combined electrical demands of ignition system and specific application. Charging system troubleshooting information is provided in Electrical System.

FUEL COMPONENTS

Fuel Pump

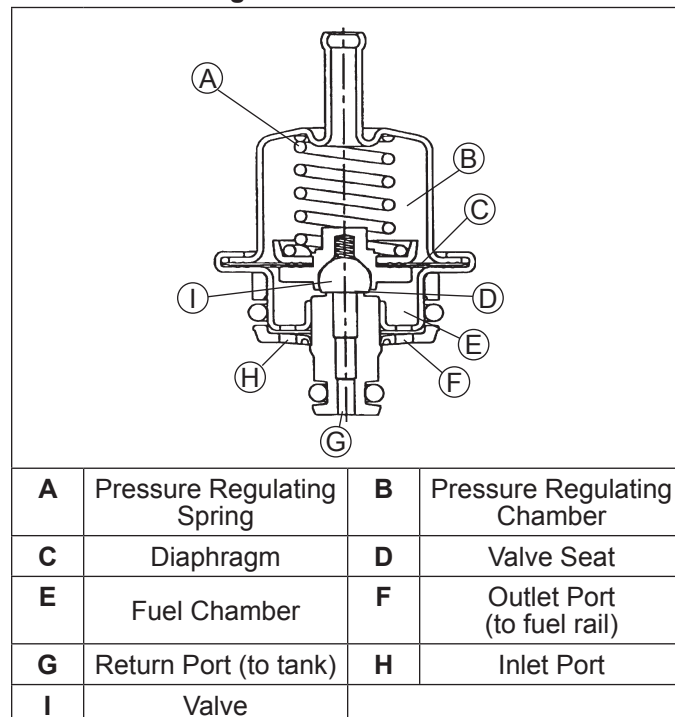
Fuel pumps are non-serviceable and must be replaced if determined to be faulty. If a fuel delivery problem is suspected, make certain pump is being activated through relay, all electrical connections are properly secured, fuses are good, and a minimum of 7.0 volts is being supplied. If during cranking, voltage drops below 7.0 volts, a reduction of fuel pressure may occur resulting in a lean starting condition. If required, testing of fuel pump and relay may be conducted.

1. Connect black hose of Pressure Tester (part of EFI Service Kit) to test valve in fuel rail. Route clear hose into a portable gasoline container or equipment fuel tank.
2. Turn on key switch to activate pump and check system pressure on gauge. If system pressure of 39 psi \pm 3 is observed, relay, fuel pump, and regulator are working properly. Turn key switch off and depress valve button on tester to relieve system pressure.
 - a. If pressure is too high, and regulator is outside tank (just down line from pump), check that return line from regulator to tank is not kinked or blocked. If return line is good, replace regulator (see Regulator on page).
 - b. If pressure is too low, install in-line T between pump and regulator and retest pressure at that point. If it is too low there also, replace fuel pump.
3. If pump did not activate (step 2), disconnect plug from fuel pump. Connect a DC voltmeter across terminals in plug, turn on key switch and observe if a minimum of 7 volts is present. If voltage is between 7 and 14, turn key switch off and connect an ohmmeter between terminals on pump to check for continuity.
 - a. If there was no continuity between pump terminals, replace fuel pump.
 - b. If voltage was below 7, test wiring harness and relay as covered in Electrical Relay section.

4. If voltage at plug was good, and there was continuity across pump terminals, reconnect plug to pump, making sure you have a good connection. Turn on key switch and listen for pump to activate.
 - a. If pump starts, repeat steps 1 and 2 to verify correct pressure.
 - b. If pump still does not operate, replace it.

Fuel Pressure Regulator

Fuel Pressure Regulator Details



Depending on application, regulator may be located in fuel tank along with fuel pump, or outside tank just down line from pump. Regulator is a sealed, non-serviceable assembly. If it is faulty, it must be separated from base/holder assembly and replaced as follows:

1. Shut engine off, make sure engine is cool, and disconnect negative (–) battery cable.
2. Depressurize fuel system through test valve in fuel rail.
3. Access regulator assembly as required and clean any dirt or foreign material away from area.
4. External Regulator:
 - a. Remove screws securing mounting bracket to regulator housing. Remove O-ring and pull regulator out of housing.
 - b. Remove snap ring and remove regulator from base/holder.

Internal (In-Tank) Regulator:

Remove screws securing retaining ring and regulator in base/holder assembly. Grasp and pull regulator out of base/holder.

EFI System

5. Always use new O-rings and hose clamps when installing a regulator. A new replacement regulator will have new O-rings already installed. Lubricate O-rings (external regulator) with light grease or oil.
6. Install new regulator by carefully pushing and rotating it slightly into base or housing.
 - a. External Regulators with Square Base Housing Only; Install a new O-ring between regulator and mounting bracket. Set mounting bracket into position.
 - b. Secure regulator in base with original retaining ring or screws. Be careful not to dent or damage body of regulator as operating performance can be affected.
7. Reassemble and connect any parts removed in step 3.
8. Reconnect negative (–) battery cable.
9. Recheck regulated system pressure at fuel rail test valve.

Fuel Rail

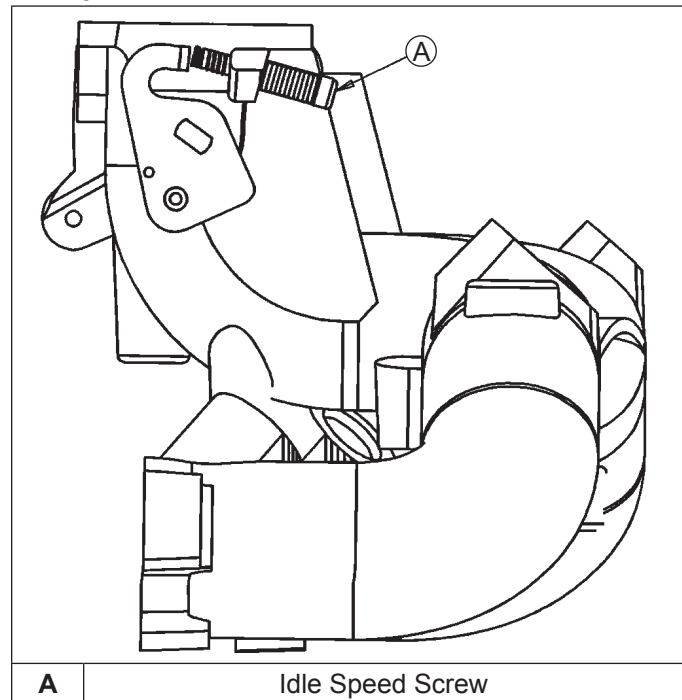
Fuel rail is mounted to throttle body/intake manifold. No specific servicing is required unless operating conditions indicate that it needs internal cleaning or replacement. It can be detached by removing mounting screws and injector retaining clips. Thoroughly clean area around all joints and relieve any pressure before starting any disassembly.

Throttle Body/Intake Manifold Assembly

Throttle body/intake manifold is serviced as an assembly, with throttle shaft, TPS, throttle plates, and idle speed adjusting screw installed. Throttle shaft rotates on needle bearings (non-serviceable), capped with rubber seals to prevent air leaks. A throttle shaft repair kit is available to replace shaft if worn or damaged. Appropriate TPS Initialization Procedure must be performed after any throttle shaft service.

IDLE SPEED ADJUSTMENT (RPM)

Idle Speed Screw Details



Adjustment Procedure

1. Make sure there are no fault codes present in ECU memory.
2. Start engine and allow it to fully warm up and establish closed looped operation (approximately 5-10 min.).
3. Place throttle control in IDLE/SLOW position and check idle speed with a tachometer. Turn idle speed screw in or out as required to obtain 1500 RPM, or idle speed specified by equipment manufacturer.
4. Idle speed adjustment can affect high idle speed setting. Move throttle control to full throttle position and check high idle speed. Adjust as necessary to 3750 RPM, or speed specified by equipment manufacturer.

INITIAL GOVERNOR ADJUSTMENT

Initial governor adjustment is especially critical on EFI engines because of accuracy and sensitivity of electronic control system. Incorrect adjustment can result in overspeed, loss of power, lack of response, or inadequate load compensation. If you encounter any of these symptoms and suspect them to be related to governor setting, following should be used to check and/or adjust governor and throttle linkage.

If governor/throttle components are all intact, but you think there may be a problem with adjustment, follow Checking Initial Adjustment to check setting. If governor lever was loosened or removed, go immediately to Setting Initial Adjustment to perform initial adjustment.

Checking Initial Adjustment

1. Unsnap plastic linkage bushing attaching throttle linkage to governor lever. Unhook damper spring from lever, separate linkage from bushing, and remove bushing from lever. Mark hole position and unhook governor spring from governor lever.
2. Pivot throttle shaft and plate into Full Throttle position, so tang of throttle shaft plate is against manifold casting. Temporarily clamp in this position.
3. Rotate governor lever and shaft counterclockwise until it stops. Use only enough pressure to hold it in that position.
4. Check how end of throttle linkage aligns with bushing hole in governor lever. It should fall in center of hole. If it doesn't, perform adjustment procedure as follows.

Setting Initial Adjustment

1. Check split where clamping screw goes through governor lever. There should be a gap of at least 1/32". If tips are touching and there is no gap present, lever should be replaced. If not already installed, position governor lever on cross shaft, but leave clamping screw loose.
2. Follow instructions in Step 2 of Checking Initial Adjustment, then reattach throttle linkage to governor lever with bushing clip. It is not necessary to reattach damper or governor springs at this time.
3. Insert a nail into hole in top of cross shaft. Using light pressure, rotate governor shaft counterclockwise as far as it will turn, then torque hex nut on clamping screw to 6.8 N·m (60 in. lb.). Make sure that governor arm has not twisted up or down after nut has been tightened.
4. Verify that governor has been set correctly. With linkage still retained in Full Throttle position (Step 2), unsnap bushing clip, separate linkage from bushing, and remove bushing from lever. Follow Steps 3 and 4 in Checking Initial Adjustment.
5. Reconnect dampening spring into its governor lever hole from bottom. Reinstall bushing and reattach throttle linkage. Reattach governor spring in marked hole.
6. Start engine and allow it to fully warm up and establish closed loop operation (approximately 5-10 min.). Check speed settings and adjust as necessary, first low idle speed, and then high speed setting.

TROUBLESHOOTING GUIDE

Engine Starts Hard or Fails to Start When Cold	Fuel pump not running.
	Engine temp sensor faulty.
	Incorrect fuel pressure.
	TPS faulty.
	TPS offset incorrect.
	Old/stale fuel.
	Low system voltage.
	Speed sensor loose or faulty.
	Faulty injectors.
	Faulty coils.
Engine Starts Hard or Fails to Start When Hot	Faulty spark plugs.
	Fuel pressure low.
	Fuel pump not running.
	Engine temp sensor faulty.
	Insufficient fuel delivery.
	TPS faulty.
	TPS offset incorrect.
	Speed sensor loose or faulty.
	Faulty injectors.
	Faulty spark plugs.

EFI System

Engine Misses, Hesitates, or Stalls Under Load	Fuel injector(s), fuel filter, fuel line, or fuel pick-up dirty/restricted.
	Dirty air cleaner.
	Insufficient fuel pressure or fuel delivery.
	Vacuum (intake air) leak.
	Improper governor setting, adjustment or operation.
	Speed sensor malfunction.
	TPS faulty, mounting problem or TPS Initialization Procedure incorrect.
	Bad coil(s), spark plug(s), or wires.
Low Power	Faulty/malfunctioning ignition system.
	Dirty air filter.
	Insufficient fuel delivery.
	Improper governor adjustment.
	Plugged/restricted exhaust.
	One injector not working.
	Basic engine problem exists.
	TPS faulty or mounting exists.
	Throttle plates in throttle body/intake manifold not fully opening to WOT stop (if equipped).

ELECTRICAL SYSTEM

NOTE: When performing voltage or continuity tests, avoid putting excessive pressure on or against connector pins. Flat pin probes are recommended for testing to avoid spreading or bending terminals.

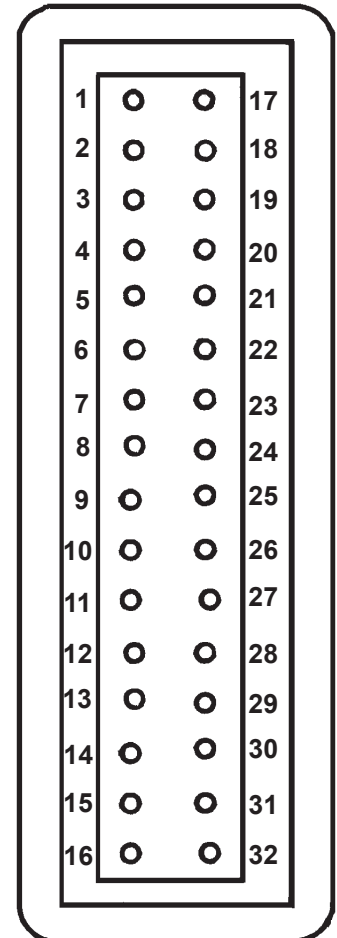
EFI system is a 12 VDC negative ground system, designed to operate down to a minimum of 7.0 volts. If system voltage drops below this level, operation of voltage sensitive components such as ECU, fuel pump, and injectors will be intermittent or disrupted, causing erratic operation or hard starting. A fully charged, 12 volt battery with a minimum of 350 cold cranking amps is important in maintaining steady and reliable system operation. Battery condition and state of charge should always be checked first when troubleshooting an operational problem.

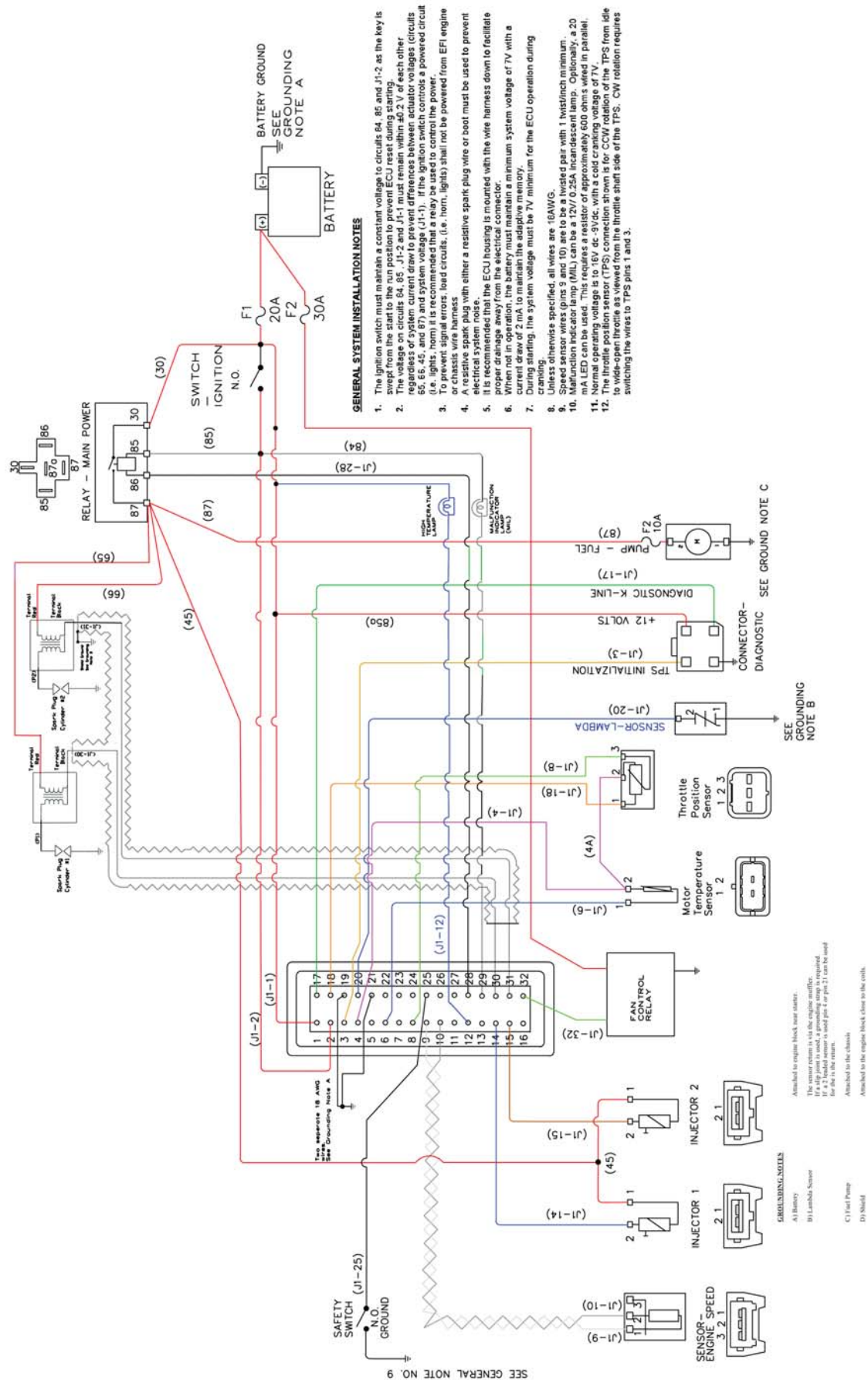
Keep in mind that EFI-related problems are more often caused by wiring harness or connections than by EFI components. Even small amounts of corrosion or oxidation on terminals can interfere with milliamp currents used in system operation. Cleaning connectors and grounds will solve problems in many cases. In an emergency situation, simply disconnecting and reconnecting connectors may clean up contacts enough to restore operation, at least temporarily.

If a fault code indicates a problem with an electrical component, disconnect ECU connector and test for continuity between component connector terminals and corresponding terminals in ECU connector using an ohmmeter. Little or no resistance should be measured, indicating that wiring of that particular circuit is OK. An illustrated listing of numerical terminal locations is provided below.


On LH775 Kohler liquid-cooled engines, ECU and corresponding wiring harness provide two additional circuits. Pin circuit 32 provides ability to control an optional OEM electric cooling fan, switching it ON and OFF at appropriate coolant temperatures using a relay. Pin circuit 12 switches on when coolant temperature is too high to operate an optional engine temperature warning light.

Pin #	Function	
1	Permanent Battery Voltage	
2	Switched Battery Voltage	
3	TPS Set; Auto-Learn Initialization Terminal	
4	Throttle Position Sensor (TPS) and Temperature Sensor Ground	
5	Not Used	
6	Oil Temperature Sensor Input	
7	Not Used	
8	Throttle Position Sensor (TPS) Input	
9	Speed Sensor Input (+)	
10	Speed Sensor Ground (–)	
11	Not Used	
12	High Temperature Warning Output	
13	Not Used	
14	Injector 1 Output	
15	Injector 2 Output	
16	Not Used	
17	Diagnostic Line	
18	Throttle Position/Temperature Sensor Supply Voltage	
19	Battery Ground	
20	Oxygen Sensor Input	
21	Battery Ground (Secondary)	
22	Not Used	
23	Not Used	
24	Not Used	
25	Safety Switch Input	
26	Not Used	
27	Not Used	
28	Main Relay Output	
29	Malfunction Indicator Light (MIL)	
30	Ignition Coil #1 Output	
31	Ignition Coil #2 Output	
32	Fan Control Output	





FUEL SYSTEM

	⚠ WARNING
	<p>Explosive Fuel can cause fires and severe burns.</p> <p>Fuel system ALWAYS remains under HIGH PRESSURE.</p>
<p>Wrap a shop towel completely around fuel pump module connector. Press release button(s) and slowly pull connector away from fuel pump module allowing shop towel to absorb any residual fuel in high pressure fuel line. Any spilled fuel must be completely wiped up immediately.</p>	

Function of fuel system is to provide sufficient delivery of fuel at system operating pressure of 39 psi \pm 3. If an engine starts hard, or turns over but will not start, it may indicate a problem with EFI fuel system. A quick test will verify if system is operating.

1. Disconnect and ground spark plug leads.
2. Complete all safety interlock requirements and crank engine for approximately 3 seconds.
3. Remove spark plugs and check for fuel at tips.
 - a. If there is fuel at tips of spark plugs, fuel pump and injectors are operating.
 - b. If there is no fuel at tips of spark plugs, check following:
1. Make sure fuel tank contains clean, fresh, proper fuel.
2. Make sure that vent in fuel tank is open.
3. Make sure fuel tank valve (if so equipped) is fully opened.
4. Make sure battery is supplying proper voltage.
5. Check that fuses are good, and that all electrical and fuel line connections are good.
6. Test fuel pump and relay operation.

FAULT CODES

ECU continuously monitors engine operation against preset performance limits. If operation is outside limits, ECU activates MIL and stores a diagnostic code in its fault memory. If component or system returns to proper function, ECU will eventually self-clear fault code and turn off MIL. If MIL stays illuminated, it warns customer that dealer service is required. Upon receipt, dealer technician can access fault code(s) to help determine what portion of system is malfunctioning.

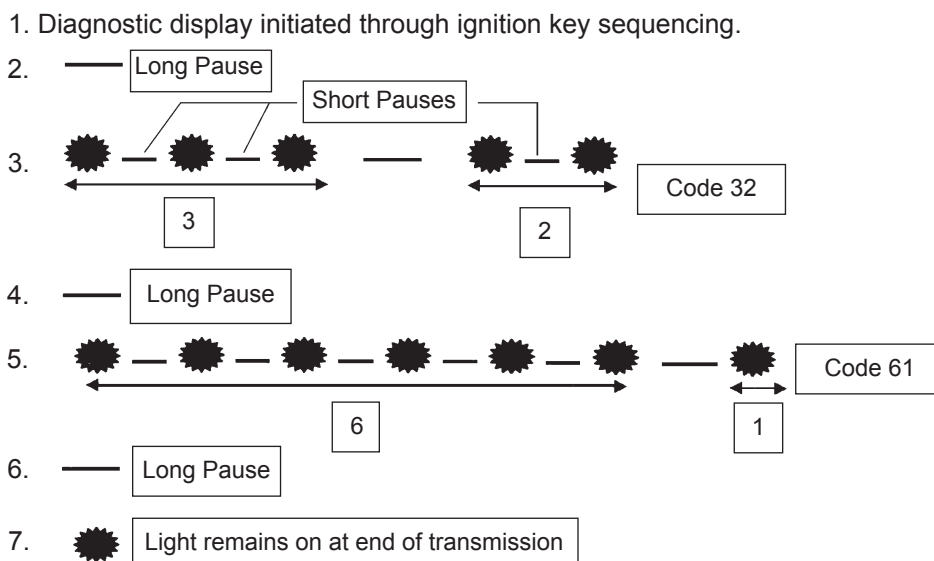
Codes are accessed through key switch and displayed as blinks or flashes of MIL. Access codes as follows.

1. Start with key switch off.
2. Turn key switch on-off-on-off-on, leaving it on in third sequence. time between sequences must be less than 2.5 seconds.
3. Any stored fault codes will then be displayed as a series of MIL blinks (from 2 to 6) representing first digit, followed by a pause, and another series of blinks (from 1 to 6) for second digit.
 - a. It's a good idea to write down codes as they appear, as they may not be in numerical sequence.
 - b. Code 61 will always be last code displayed, indicating end of code transmission. If code 61 appears immediately, no other fault codes are present.

After problem has been corrected, fault codes may be cleared as follows.

1. Disconnect negative (–) battery cable from battery terminal, or remove main fuse for ECU for approximately 1 minute.
2. Reconnect cable and tighten securely, or reinstall main fuse. Start engine and allow it to run for several minutes. MIL should remain off if problem was corrected, and fault codes should not reappear (codes 31, 32, 33, and 34 may require 10-15 minutes of running to reappear).

Example of Diagnostic Display



EFI System

Following chart lists fault codes, what they correspond to, and what visual indications will be. Following chart is a list of individual codes with an explanation of what triggers them, what symptoms might be expected, and probable causes.

Diagnostic Code Summary

Blink Code	OBD2 P-Code	Condition or Failure Description	MIL Illuminated	Note
–	–	No RPM Signal	Y	
21	P0335	Loss of Synchronization	Y	
22	P0122	TPS - Open or Short Circuit to Ground	Y	
22	P0123	TPS - Short Circuit to Battery	Y	
23	P0601	Defective ECU	Y	
24	-	Engine Speed Sensor	Y	4
31	P0174	System too Lean	Y	2
31	P0132	O2 Sensor Circuit: Shorted to Battery	Y	1
32	P0134	O2 Sensor Circuit: No Activity Detected	Y	
33	P0175	System too Rich	Y	3
33	P0020	O2 Sensor Control at Upper Limit	Y	
34	P0171	Maximum Adaption Limit Reached	Y	
34	P0172	Minimum Adaption Limit Reached	Y	
42	P0117	Temperature Sensor Circuit: Shorted to Ground	Y	
42	P0118	Temperature Sensor Circuit: Open Circuit or Short to Battery	Y	
43	P1670	Failure Completing Autolearn - TPS Offset below minimum allowable limit	Y	
44	P1671	Failure Completing Autolearn - TPS Offset above maximum allowable limit	Y	
51	P1260	Injector 1 - Open Circuit	Y	
51	P0261	Injector 1 - Short Circuit to Ground	Y	
51	P0262	Injector 1 - Short Circuit to Battery	Y	
52	P1263	Injector 2 - Open Circuit	Y	
52	P0264	Injector 2 - Short Circuit to Ground	Y	
52	P0265	Injector 2 - Short Circuit to Battery	Y	
54	P0655	High Temperature Warning Lamp Circuit Open	N	4
54	P1657	High Temperature Warning Lamp Circuit Shortened to Ground	N	4
54	P1658	High Temperature Warning Lamp Circuit Shorted to Voltage	N	4
55	P1651	MIL Lamp - Open Circuit	N	
55	P1652	MIL Lamp - Short Circuit to Ground	Y	
55	P1653	MIL Lamp - Short Circuit to Battery	Y	
56	P1231	Pump Relay - Open Circuit	Y	
56	P1232	Pump Relay - Short Circuit to Ground	Y	
56	P1233	Pump Relay - Short Circuit to Battery	Y	
58	P1480	Cooling Fan Driver Circuit Open	N	
58	P1481	Cooling Fan Driver Circuit Shorten to Ground	N	
58	P1482	Cooling Fan Driver Circuit Shorten to Voltage	N	
61	–	End of Code Transmission	N	

NOTE: 1. O2 Sensor Short to Battery diagnostic detection is disabled with SAS fuel-cutoff calibrated out.

2. System too Lean used to be O2 Sensor - Short to Ground (P0131).

3. System too Rich used to be O2 Sensor Control at Lower Limit (P0019).

4. Will not blink out.

MIL Lamp is always switched OFF when failure is SPORADIC.

DIAGNOSTIC CODE SUMMARY

Code 21

Component:	Engine Speed Sensor
Fault:	ECU receiving inconsistent tooth count signals from speed sensor.
Condition:	Possible misfire as ECU attempts to resynchronize, during which time fuel and spark calculations are not made.
Conclusion:	<p>Engine Speed Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring. • Sensor loose or incorrect air gap. • Flywheel key sheared <p>Speed Sensor Ring Gear Related</p> <ul style="list-style-type: none"> • Damaged teeth. • Varying gap (gear loose/out of alignment). <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuits 9 and/or 10 wiring or connectors. • Shielding for pin circuits 9 and/or 10 damaged or not properly grounded. • Poor or improper grounds in system (battery, ECU, oxygen sensor, shielding, fuel pump, ignition output). • Pin circuits 9 and/or 10 routed near noisy electrical signals (coils, spark plug lead, plug connector). <p>ECU/Harness Related</p> <ul style="list-style-type: none"> • ECU-to-harness connection problem. <p>Ignition System Related</p> <ul style="list-style-type: none"> • Non-resistor spark plug(s) used.

Code 22

Component:	Throttle Position Sensor (TPS)
Fault:	Unrecognizable signal is being sent from sensor (too high, too low, inconsistent).
Condition:	A limp-home operating mode occurs, with an overall decrease in operating performance and efficiency. Fuel delivery is based upon oxygen sensor and five mapped values only. Rich running (black smoke) will occur until closed loop operation is initiated. A stumble or misfire on hard acceleration and/or erratic operation may be exhibited.
Conclusion:	<p>TPS Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring. • Sensor output affected or disrupted by dirt, grease, oil, wear, or breather tube position (must be to side opposite TPS). • Sensor loose on throttle body manifold. <p>Throttle Body Related</p> <ul style="list-style-type: none"> • Throttle shaft or bearings worn/damaged. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuits 4, 8, and/or 18 damaged (wiring, connectors). • Pin circuits 4, 8, and/or 18 routed near noisy electrical signal (coils, alternator). • Intermittent 5 volt source from ECU (pin circuit 18). <p>ECU/Harness Related</p> <ul style="list-style-type: none"> • ECU-to-harness connection problem.

Code 23

Component:	ECU
Fault:	ECU is unable to recognize or process signals from its memory.
Condition:	Engine will not run.
Conclusion:	<p>ECU (internal memory problem).</p> <ul style="list-style-type: none"> • Diagnosable only through elimination of all other system/component faults.

EFI System

Code 24 (Will not blink out)

Component:	Engine Speed Sensor
Fault:	No tooth signal from speed sensor. MIL light will not go out when cranking.
Condition:	None-engine will not start or run as ECU is unable to estimate speed.
Conclusion:	<p>Engine Speed Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring. • Sensor loose or air gap incorrect. <p>Speed Sensor Wheel Related</p> <ul style="list-style-type: none"> • Damaged teeth. • Gap section not registering. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuit wiring or connectors. Pin(s) 9 and/or 10. <p>ECU/Harness Related</p> <ul style="list-style-type: none"> • ECU-to-harness connection problem.

Code 32

Component:	Oxygen Sensor
Fault:	No change in sensor output signal.
Condition:	Open loop operation only, may cause a drop in system performance and fuel efficiency.
Conclusion:	<p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuit wiring or connectors. Pin 20. <p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring problem. • Sensor contaminated or damaged. • Sensor below minimum operating temperature (375°C, 709°F). • Poor ground path from sensor to engine (sensor grounds through shell, see Oxygen Sensor section).

Code 31

Component:	Fuel Mixture or Oxygen Sensor
Fault:	System too lean. Oxygen sensor not sending expected voltage to ECU.
Condition:	System operates under open loop control only. Until fault is detected and registered by ECU, engine will run rich if oxygen sensor is shorted to ground or lean if it is shorted to battery voltage. After fault is detected, performance can vary, depending on cause. If performance is pretty good, problem is probably with oxygen sensor, wiring, or connectors. If engine is still running rich (laboring, short on power) or lean (popping or misfiring), fuel mixture is suspect, probably incorrect TPS initialization or low fuel pressure.
Conclusion:	<p>TPS Initialization Incorrect</p> <ul style="list-style-type: none"> • Lean condition (check oxygen sensor signal with VOA and see Oxygen Sensor section). <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuit wiring or connectors. Pin 20. <p>Low Fuel Pressure</p> <p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring problem. • Exhaust leak. • Poor ground path to engine (sensor is case grounded). <p>Poor system ground from ECU to engine, causing rich running while indicating lean.</p>

Code 33

Component:	Oxygen Sensor/Fuel System
Fault:	System too rich. Temporary fuel adaptation control is at upper limit.
Condition:	<p>Fuel Supply Related (nothing lean-only rich)</p> <ul style="list-style-type: none"> ● Restricted return line causing excessive fuel pressure. ● Fuel inlet screen plugged (in-tank fuel pump only). ● Incorrect fuel pressure at fuel rail. <p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> ● Sensor connector or wiring problem. ● Sensor contaminated or damaged. ● Exhaust leak. ● Poor ground path. ● Pin circuit wiring or connectors. Pin 20. <p>TPS Sensor Related</p> <ul style="list-style-type: none"> ● Throttle plate position incorrectly set or registered during Initialization. ● TPS problem or malfunction. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> ● Difference in voltage between sensed voltage (pin 2) and actual injector voltage (circuit 45/45A). <p>Systems Related</p> <ul style="list-style-type: none"> ● Ignition (spark plug, plug wire, ignition coil). ● Fuel (fuel type/quality, injector, fuel pump, fuel pressure). ● Combustion air (air cleaner dirty/restricted, intake leak, throttle bores). ● Base engine problem (rings, valves). ● Exhaust system leak. ● Fuel in crankcase oil. ● Blocked or restricted fuel return circuit to tank. <p>ECU/Harness Related</p> <ul style="list-style-type: none"> ● ECU-to-harness connection problem.

Code 34

Component:	Oxygen Sensor/Fuel System Components
Fault:	Long term fuel adaptation control is at upper or lower limit.
Condition:	System operates closed loop. No appreciable performance loss as long as temporary adaptation can provide sufficient compensation.
Conclusion:	<p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> ● Sensor connector or wiring problem. ● Sensor contaminated or damaged. ● Exhaust leak. ● Poor ground path. ● Pin circuit wiring or connectors. Pin 20. <p>TPS Sensor Related</p> <ul style="list-style-type: none"> ● Throttle plate position incorrect during Initialization procedure. ● TPS problem or malfunction. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> ● Difference in voltage between sensed voltage (pin 2) and actual injector voltage (circuit 45/45A). ● Problem in wiring harness. ● ECU-to-harness connection problem. <p>Systems Related</p> <ul style="list-style-type: none"> ● Ignition (spark plug, plug wire, ignition coil). ● Fuel (fuel type/quality, injector, fuel pressure, fuel pump). ● Combustion air (air cleaner dirty/restricted, intake leak, throttle bores). ● Base engine problem (rings, valves). ● Exhaust system leak (muffler, flange, oxygen sensor mounting boss, etc.). ● Fuel in crankcase oil. ● Altitude. ● Blocked or restricted fuel return circuit to tank.

EFI System

Code 42

Component:	Engine (Oil) Temperature Sensor
Fault:	Not sending proper signal to ECU.
Condition:	Engine may be hard to start because ECU can't determine correct fuel mixture.
Conclusion:	<p>Temperature Sensor Related</p> <ul style="list-style-type: none"> • Sensor wiring or connection. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuits 4, 6 and/or (4A) damaged (wires, connectors) or routed near noisy signal (coils, alternator, etc.). • ECU-to-harness connection problem. <p>System Related</p> <ul style="list-style-type: none"> • Engine is operating above 176°C (350°F) temperature sensor limit.

Code 43 and 44

Component:	TPS Auto-Learn initialization function failed, throttle angle out of learning range.
Fault:	While performing TPS Auto-Learn function, measured throttle angle was not within acceptable limits.
Condition:	MIL illuminated. Engine will continue to run but not properly. Upon restart TPS Auto-Learn function will run again unless voltage to ECU disconnected to clear memory.
Conclusion:	<p>TPS Related</p> <ul style="list-style-type: none"> • TPS rotated on throttle shaft assembly beyond allowable range. • TPS bad. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Broken or shorted wire in harness. <ul style="list-style-type: none"> ECU pin 18 to TPS pin 1. ECU pin 4 to TPS pin 2. ECU pin 8 to TPS pin 3. <p>Throttle Body Related</p> <ul style="list-style-type: none"> • Throttle shaft inside TPS worn, broken, or damaged. • Throttle plate loose or misaligned. • Throttle plate bent or damaged allowing extra airflow past, or restricting movement. <p>ECU Related</p> <ul style="list-style-type: none"> • Circuit providing voltage or ground to TPS damaged. • TPS signal input circuit damaged.

Code 51

Component:	Injector #1 circuit open, shorted to ground, or shorted to battery.
Fault:	Injector #1 is not functioning because circuit is open, shorted to ground, or shorted to battery.
Condition:	Engine will run very poorly with only one cylinder functioning.
Conclusion:	<p>Injector Related</p> <ul style="list-style-type: none"> • Injector coil shorted or opened. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Broken or shorted wire in harness. <ul style="list-style-type: none"> ECU pin 14 to injector pin 2. ECU pin 28 to fuel pump relay pin 86. Note: after key-off then key-on code 56 would be set also. Fuel pump relay pin 87 to injector pin 1. • Open main fuse F1. <p>Fuel Pump Relay Related</p> <ul style="list-style-type: none"> • Bad fuel pump relay. Primary side functional but pin 30 to pin 87 remains open. Primary side pin 85 to pin 86 is either open, or shorted during engine operation. Note: after key-off then key-on code 56 would be set also. <p>ECU Related</p> <ul style="list-style-type: none"> • Circuit controlling injector #1 damaged. • Circuit controlling fuel pump relay damaged.

Code 52

Component:	Injector #2 circuit open, shorted to ground, or shorted to battery.
Fault:	Injector #2 is not functioning because circuit is open, shorted to ground, or shorted to battery.
Condition:	Engine will run very poorly with only one cylinder functioning.
Conclusion:	<p>Injector Related</p> <ul style="list-style-type: none"> • Injector coil shorted or opened. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Broken or shorted wire in harness. ECU pin 15 to injector pin 2. ECU pin 28 to fuel pump relay pin 86. Note: after key-off then key-on code 56 would be set also. Fuel pump relay pin 87 to injector pin 1. • Opened main fuse F1. <p>Fuel Pump Relay Related</p> <ul style="list-style-type: none"> • Bad fuel pump relay. Primary side functional, but pin 30 to pin 87 remains open. Primary side pin 85 to pin 86 is open or shorted during engine operation. Note: after key-off then key-on code 56 would be set also. <p>ECU Related</p> <ul style="list-style-type: none"> • Circuit controlling injector #2 damaged. • Circuit controlling fuel pump relay damaged.

Code 55

Component:	MIL (Diagnostic lamp) circuit open, shorted to ground, or shorted to battery.
Fault:	MIL is not functioning because circuit is open, shorted to ground, or shorted to battery.
Condition:	Engine will run normally if no other errors are present.
Conclusion:	<p>MIL (diagnostic lamp) Related</p> <ul style="list-style-type: none"> • MIL element opened or element shorted to ground. • Lamp missing. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Broken or shorted wire in harness. ECU pin 29 to lamp open or shorted. <p>Vehicle Wiring Harness Related</p> <ul style="list-style-type: none"> • Broken or shorted wire in harness. Power lead to MIL open or shorted. <p>ECU Related</p> <ul style="list-style-type: none"> • Circuit controlling lamp damaged.

Code 56

Component:	Fuel pump relay circuit open, shorted to ground, or shorted to battery.
Fault:	Fuel pump, ignition coils, and fuel injectors will not function because fuel pump relay circuit is either open, shorted to ground, or may be ON continuously if shorted to battery.
Condition:	Engine will not run, or fuel pump will continue to run when switch is off.
Conclusion:	<p>Fuel Pump Relay Related</p> <ul style="list-style-type: none"> • Bad fuel pump relay. Primary side open or shorted. <p>Fuel Pump Related</p> <ul style="list-style-type: none"> • Fuel pump open or shorted internally. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Fuel pump fuse F1 open. • Broken or shorted wire in harness. ECU pin 28 to fuel pump relay pin 86. Ignition switch to fuel pump relay pin 85. <p>ECU Related</p> <ul style="list-style-type: none"> • Circuit controlling fuel pump relay damaged.

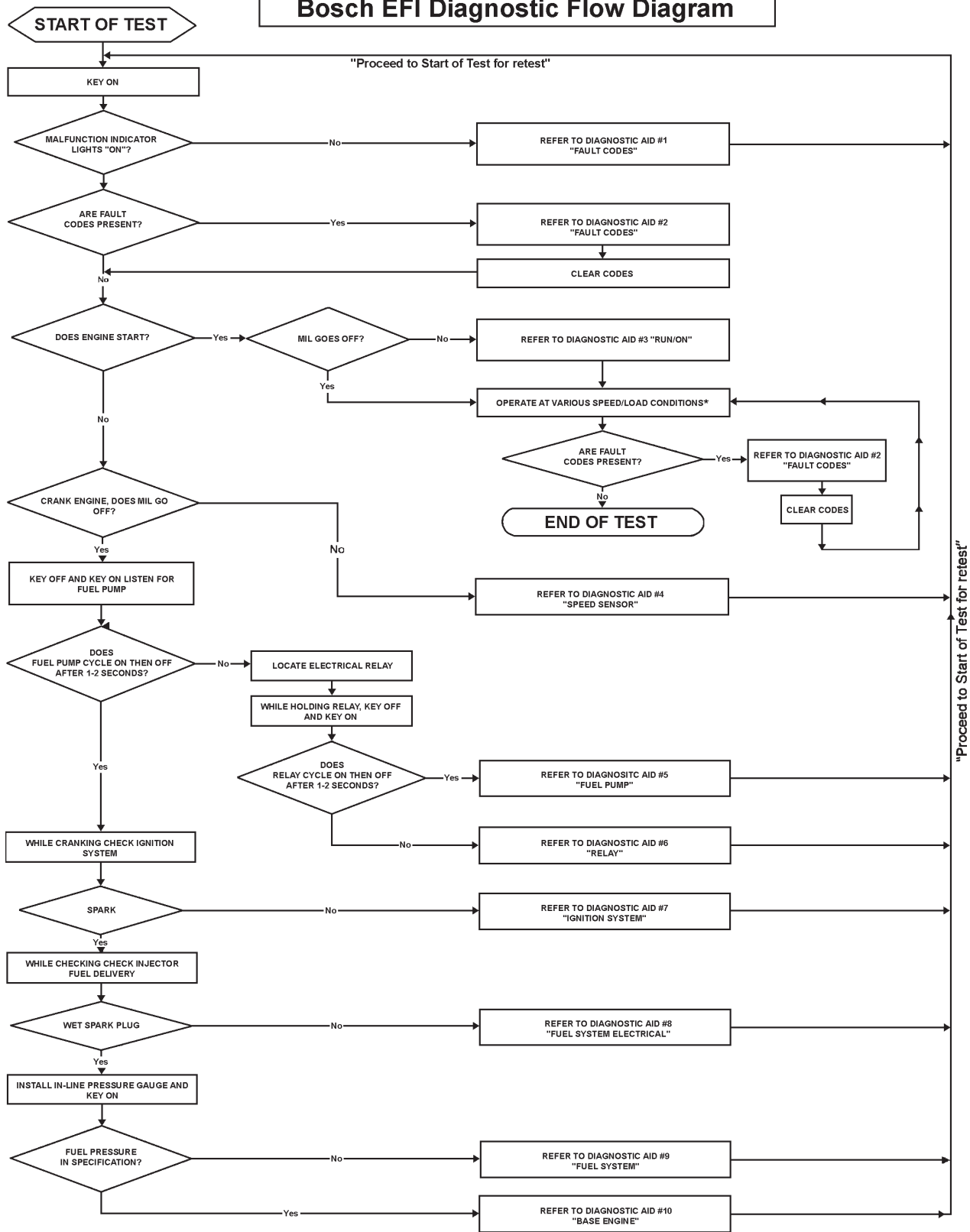
Code 61

Component:	
Fault:	
Condition:	Denotes end of fault codes. If signaled first, no other fault codes are present.
Conclusion:	

Troubleshooting Flow Chart

Following flow chart provides an alternative method of troubleshooting EFI system. Chart will enable you to review entire system in about 10-15 minutes. Using chart, accompanying diagnostic aids (listed after chart), and any signaled fault codes, you should be able to quickly locate any problems within system.

Bosch EFI Diagnostic Flow Diagram



*Operate for an appropriate period of time based upon original fault codes.

Flow Chart Diagnostic Aids

Diagnostic Aid #1 SYSTEM POWER (MIL does not illuminate when key is turned ON)

Possible causes:

- Battery
- Main system fuse
- MIL light bulb burned out
- MIL electrical circuit problem. Pin circuits 29 and 84.
- Ignition switch
- Permanent ECU power circuit problem. Pin circuit 1.
- Switched ECU power circuit problem. Pin circuit 2.
- ECU grounds
- ECU

Diagnostic Aid #2 FAULT CODES (Refer to detailed fault code listing before flow chart and servicing information for respective components)

- Code 21 - Engine Speed Synchronization
- Code 22 - Throttle Position Sensor (TPS)
- Code 23 - Engine Control Unit (ECU)
- Code 31 - Oxygen Sensor
- Code 32 - Oxygen Sensor
- Code 33 - Fuel System (temporary adaptation factor)
- Code 34 - Fuel System (permanent adaptation factor)
- Code 42 - Engine (Coolant) Temperature Sensor
- Code 43 - TPS Auto-Learn Initialization Function. (Below Min. Limit)
- Code 44 - TPS Auto-Learn Initialization Function. (Above Max. Limit)
- Code 51 - Injector 1
- Code 52 - Injector 2
- Code 55 - MIL (Diagnostic Light)
- Code 56 - Pump Relay
- Code 61 - End of Fault/Blink Code Transmission.

Diagnostic Aid #3 RUN/ON (MIL remains ON while engine is running)

Possible causes:

- Fault codes which turn on MIL when engine is running.
 - Code 21 - Engine Speed Synchronization
 - Code 22 - Throttle Position Sensor (TPS)
 - Code 23 - Engine Control Unit (ECU)
 - Code 31 - Oxygen Sensor (shorted)
 - Code 34 - Fuel System (permanent adaptation at limit)
 - Code 42 - Engine (Coolant) Temperature Sensor
 - Code 43 - TPS Auto-Learn Initialization Function (Below Min. Limit)
 - Code 44 - TPS Auto-Learn Initialization Function (Above Max. Limit)
 - Code 51 - Injector 1
 - Code 52 - Injector 2
 - Code 55 - MIL (Diagnostic Light)
 - Code 56 - Pump Relay
- MIL circuit grounded between light and ECU. Pin circuit 29.
- ECU

NOTE: MIL (diagnostic light) used must be a 1/4 watt incandescent lamp. An LED style light will stay on continuously (dim) and should not be used.

Diagnostic Aid #4 SPEED SENSOR (MIL does not turn off during cranking) Indicates ECU is not receiving a signal from speed sensor.

Possible causes:

- Speed sensor
- Speed sensor circuit problem. Pin circuits 9 and 10.
- Speed sensor/toothed wheel air gap
- Toothed wheel
- Flywheel key sheared
- ECU

Diagnostic Aid #5 FUEL PUMP (fuel pump not turning on)

Possible causes:

- Fuel pump fuse
- Fuel pump circuit problem. Circuits 30, 87, and relay.
- Fuel pump

Diagnostic Aid #6 RELAY (relay not operating)

Possible causes:

- Safety switches/circuit(s) problem. Circuit 25.
- Relay circuit(s) problem. Circuits 28, 85, 30, and 87.
- Relay
- ECU grounds
- ECU

Diagnostic Aid #7 IGNITION SYSTEM (no spark)

Possible causes:

- Spark plug
- Plug wire
- Coil
- Coil circuit(s). Circuits 30, 31, 65, 66, relay and relay circuit 30.
- ECU grounds
- ECU

Diagnostic Aid #8 FUEL SYSTEM-ELECTRICAL (no fuel delivery)

Possible causes:

- No fuel
- Air in fuel rail
- Fuel valve shut off
- Fuel filter/line plugged
- Injector circuit(s). Circuits 14, 15, 45 and 4A.
- Injector
- ECU grounds
- ECU

Diagnostic Aid #9 FUEL SYSTEM (fuel pressure)

Possible causes for low fuel system pressure:

- Low fuel
- Fuel filter plugged
- Fuel supply line plugged
- Pressure regulator
- Fuel pump

Possible causes for high fuel system pressure:

- Pressure regulator
- Fuel return line plugged or restricted.

EFI System

Diagnostic Aid #10 BASIC ENGINE (cranks but will not run)

Possible causes:

- Refer to basic engine troubleshooting charts within service manual.

Common Complaints/Problems

Following are some of most common complaints or problems reported by customers. For each problem, you will find a list of most likely causes or areas to be investigated. Always start by checking if there are any stored fault codes to guide you in right direction.

Engine starts hard or fails to start when cold. (Code 31, 42, 51, 52, 56)

- Fuel pump or relay, not activating/operational.
- Engine (Coolant) Temperature sensor faulty.
- Fuel pressure insufficient/incorrect.
- Fuel injector(s) leaking.
- Fuel injector(s), fuel filter, fuel line, or fuel pick-up dirty, clogged, or restricted.
- Speed sensor malfunction.
- Stale fuel.
- Low system voltage.
- Bad spark plug(s) or coil(s).
- Base ignition timing incorrect.

Engine starts hard or fails to start when warm. (Code 42, 51, 52)

- Insufficient fuel system pressure.
- Engine (Coolant) Temperature sensor faulty.
- Fuel injector(s) leaking.
- Fuel injector(s), fuel filter, fuel line, or fuel pick-up dirty/restricted.
- Low fuel pressure.
- Wrong grade of fuel.
- Bad spark plug(s) or coil(s).
- Low system voltage.
- Speed sensor problem.
- Base ignition timing problem.

Engine stalls or idles roughly. (Code 22, 31, 34, 42, 43, 51, 52)

- Vacuum (intake air) leak.
- Fuel injector(s), fuel filter, fuel line, or fuel pick-up dirty/clogged/restricted.
- Insufficient fuel pressure/delivery.
- Engine (Coolant) Temperature sensor faulty.
- TPS faulty or TPS Initialization Procedure incorrect.
- Leaking fuel injector O-rings.
- Bad spark plug(s) or coil(s).

Engine idles too fast (after full warm-up).

- Throttle linkage binding or not returning to idle position.
- Idle speed adjustment incorrect.
- Vacuum (intake air) leak.
- Leaking fuel injector O-rings (injector to manifold).
- Engine (Coolant) Temperature sensor faulty.
- TPS faulty or TPS Initialization Procedure incorrect.
- Base ignition timing incorrect.

Engine misses, hesitates, or stalls under load. (Code 22, 31, 34, 43, 44, 51, 52)

- Fuel injector(s), fuel filter, fuel line, or fuel pick-up dirty/restricted.
- Dirty air cleaner.
- Insufficient fuel pressure or fuel delivery.
- Vacuum (intake air) leak.
- Improper governor setting, adjustment or operation.
- Speed sensor malfunction.
- TPS faulty, mounting problem or TPS Initialization Procedure incorrect.
- Bad coil(s), spark plug(s), or wires.
- Base ignition timing incorrect.

Low Power. (51, 52)

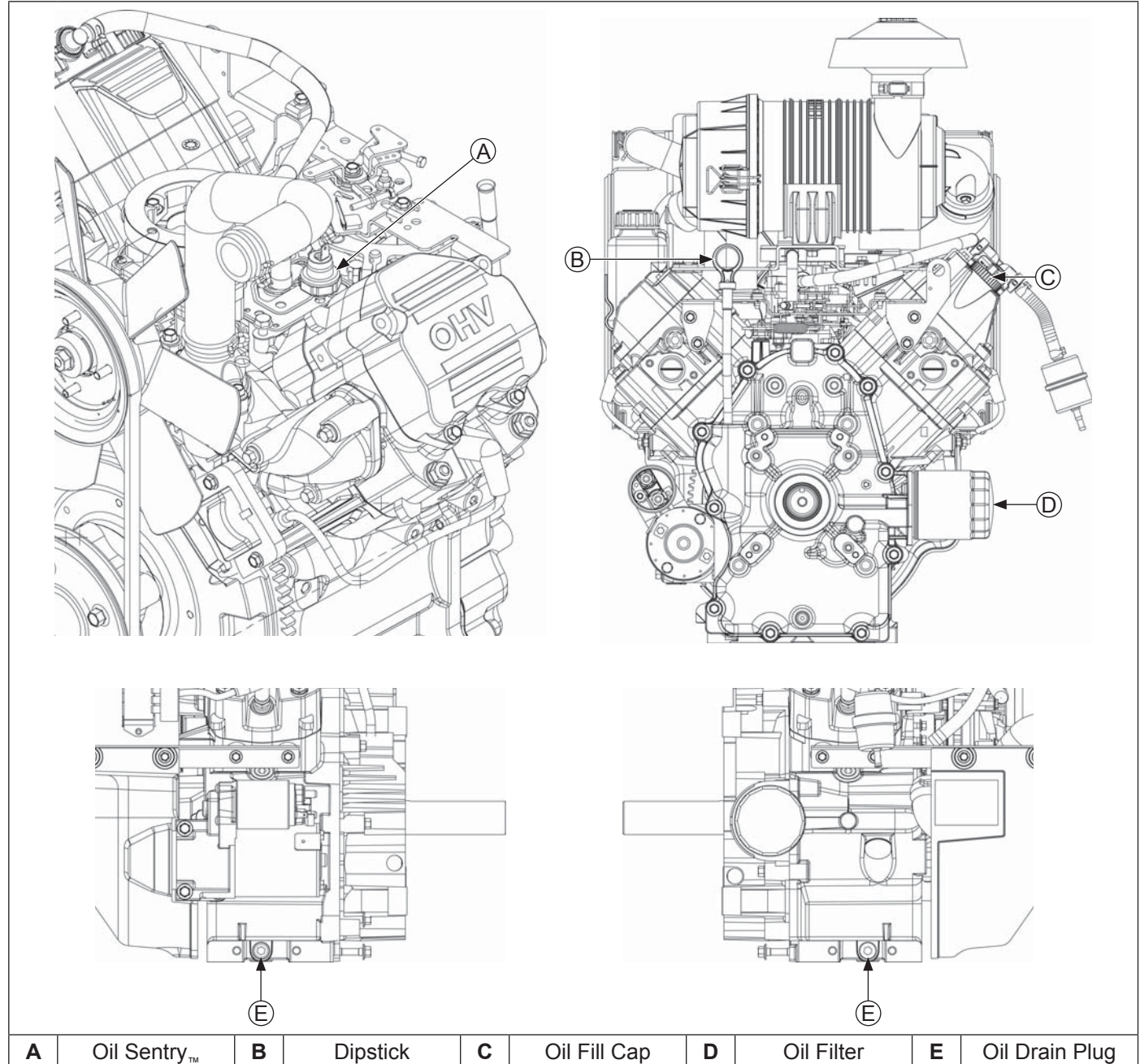
- Throttle plates in throttle body/intake manifold not fully opening to WOT stop (if so equipped).
- Insufficient fuel delivery.
- Dirty air filter.
- Faulty/malfunctioning ignition system.
- TPS faulty or mounting problem.
- Basic engine problem exists.
- Improper governor adjustment.
- Plugged/restricted exhaust.
- One injector not working.
- One spark plug, coil, or wire not working.

Lubrication System

This engine uses a full pressure lubrication system. This system delivers oil under pressure to crankshaft, camshaft and connecting rod bearing surfaces. In addition to lubricating bearing surfaces, lubrication system supplies oil to hydraulic valve lifters.

A high-efficiency gerotor pump is located in closure plate. Oil pump maintains high oil flow and oil pressure, even at low speeds and high operating temperatures. A pressure relief valve in closure plate limits maximum pressure of system.

Lubrication Components



Lubrication System

OIL RECOMMENDATIONS

Refer to Maintenance.

CHECK OIL LEVEL

NOTE: To prevent extensive engine wear or damage, never run engine with oil level below or above operating range indicator on dipstick.

Ensure engine is cool. Clean oil fill/dipstick areas of any debris.

1. Remove dipstick; wipe oil off.
2. Reinsert dipstick into tube; press completely down.
3. Remove dipstick; check oil level. Level should be at top of indicator on dipstick.
4. If oil is low on indicator, add oil up to top of indicator mark.
5. Reinstall and secure dipstick.

CHANGE OIL AND FILTER

Change oil while engine is warm.

1. Clean area around oil fill cap/dipstick, drain plug/oil drain valve. Remove drain plug and oil fill cap/dipstick. Allow oil to drain completely.
2. Clean area around oil filter. Place a container under filter to catch any oil and remove filter. Wipe off mounting surface. Reinstall drain plug. Torque to 13.6 N·m (10 ft. lb.).
3. Place new filter in shallow pan with open end up. Fill with new oil until oil reaches bottom of threads. Allow 2 minutes for oil to be absorbed by filter material.
4. Apply a thin film of clean oil to rubber gasket on new filter.
5. Refer to instructions on oil filter for proper installation.
6. Fill crankcase with new oil. Level should be at top of indicator on dipstick.

OIL SENTRY™ (if equipped)

This switch is designed to prevent engine from starting in a low oil or no oil condition. Oil Sentry™ may not shut down a running engine before damage occurs. In some applications this switch may activate a warning signal. Read your equipment manuals for more information.

Oil Sentry™ pressure switch is installed in closure plate pressure port. On engines not equipped with Oil Sentry™ installation hole is sealed with a 1/8-27 N.P.T.F. pipe plug.

Installation

1. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to threads of switch.
2. Install switch into tapped hole in closure plate.
3. Torque switch to 10.1 N·m (90 in. lb.).

Testing

Compressed air, a pressure regulator, pressure gauge, and a continuity tester are required to test switch.

1. Connect continuity tester across blade terminal and metal case of switch. With 0 psi pressure applied to switch, tester should indicate continuity (switch closed).
2. Gradually increase pressure to switch. As pressure increases through range of 7-11 psi tester should indicate a change to no continuity (switch open). Switch should remain open as pressure is increased to 90 psi maximum.
3. Gradually decrease pressure through range of 7-11 psi. Tester should indicate a change to continuity (switch closed) down to 0 psi.
4. Replace switch if it does not operate as specified.

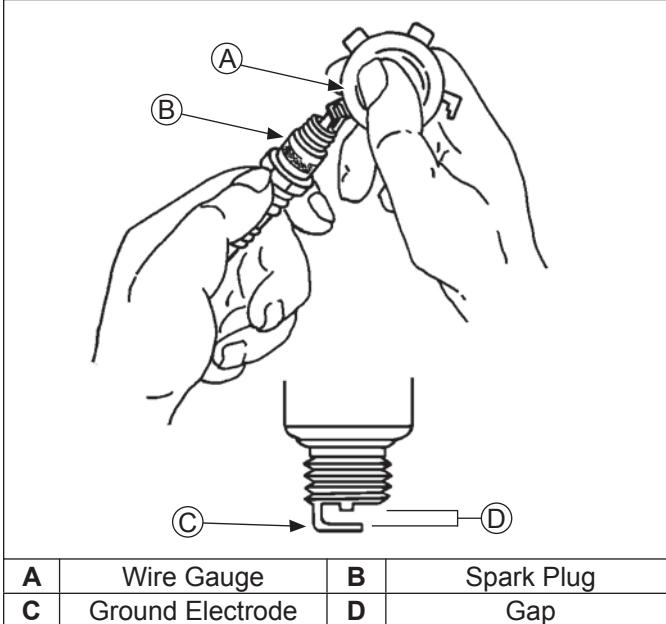
SPARK PLUGS



⚠ CAUTION

Electrical Shock can cause injury.
Do not touch wires while engine is running.

Spark Plug Component and Details



NOTE: Do not clean spark plug in a machine using abrasive grit. Some grit could remain in spark plug and enter engine causing extensive wear and damage.

Engine misfire or starting problems are often caused by a spark plug that has improper gap or is in poor condition.

Engine is equipped with following spark plugs:

Gap	0.76 mm (0.03 in.)
Thread Size	14 mm
Reach	19.1 mm (3/4 in.)
Hex Size	15.9 mm (5/8 in.)

Refer to Maintenance for Repairs/Service Parts.

Service

Clean out spark plug recess. Remove plug and replace.

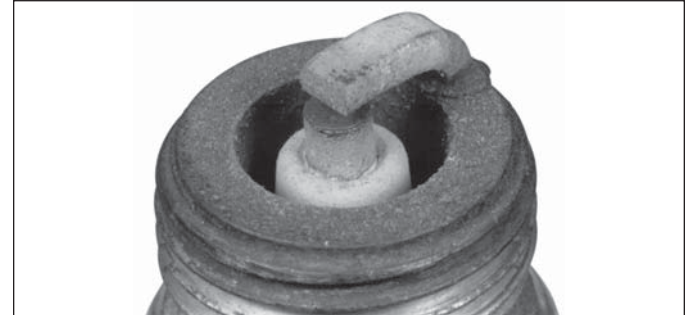
1. Check gap using wire feeler gauge. Adjust gap to 0.76 mm (0.03 in.).
2. Install plug into cylinder head.
3. Torque plug to 27 N·m (20 ft. lb.).

Inspection

Inspect each spark plug as it is removed from cylinder head. Deposits on tip are an indication of general condition of piston rings, valves, and carburetor.

Normal and fouled plugs are shown in following photos:

Normal



Plug taken from an engine operating under normal conditions will have light tan or gray colored deposits. If center electrode is not worn, plug can be set to proper gap and reused.

Worn



On a worn plug, center electrode will be rounded and gap will be greater than specified gap. Replace a worn spark plug immediately.

Wet Fouled



A wet plug is caused by excess fuel or oil in combustion chamber. Excess fuel could be caused by a restricted air cleaner, a carburetor problem, or operating engine with too much choke. Oil in combustion chamber is usually caused by a restricted air cleaner, a breather problem, worn piston rings, or valve guides.

Electrical System

Carbon Fouled



Soft, sooty, black deposits indicate incomplete combustion caused by a restricted air cleaner, over rich carburetion, weak ignition, or poor compression.

Overheated



Chalky, white deposits indicate very high combustion temperatures. This condition is usually accompanied by excessive gap erosion. Lean carburetor settings, an intake air leak, or incorrect spark timing are normal causes for high combustion temperatures.

BATTERY

A 12-volt battery with 400 cold cranking amps (cca) is generally recommended for starting in all conditions. A smaller capacity battery is often sufficient if an application is started only in warmer temperatures. Refer to following table for minimum capacities based on anticipated ambient temperatures. Actual cold cranking requirement depends on engine size, application, and starting temperatures. Cranking requirements increase as temperatures decrease and battery capacity shrinks. Refer to equipment's operating instructions for specific battery requirements.

Battery Size Recommendations

Temperature	Battery Required
Above 32°F (0°C)	300 cca minimum
0°F to 32°F (-18°C to 0°C)	300 cca minimum
-5°F to 0°F (-21°C to -18°C)	300 cca minimum
-10°F (-23°C) or below	400 cca minimum

If battery charge is insufficient to turn over engine, recharge battery.

Battery Maintenance

Regular maintenance is necessary to prolong battery life.

Battery Test

To test battery, follow manufacturer's instructions.

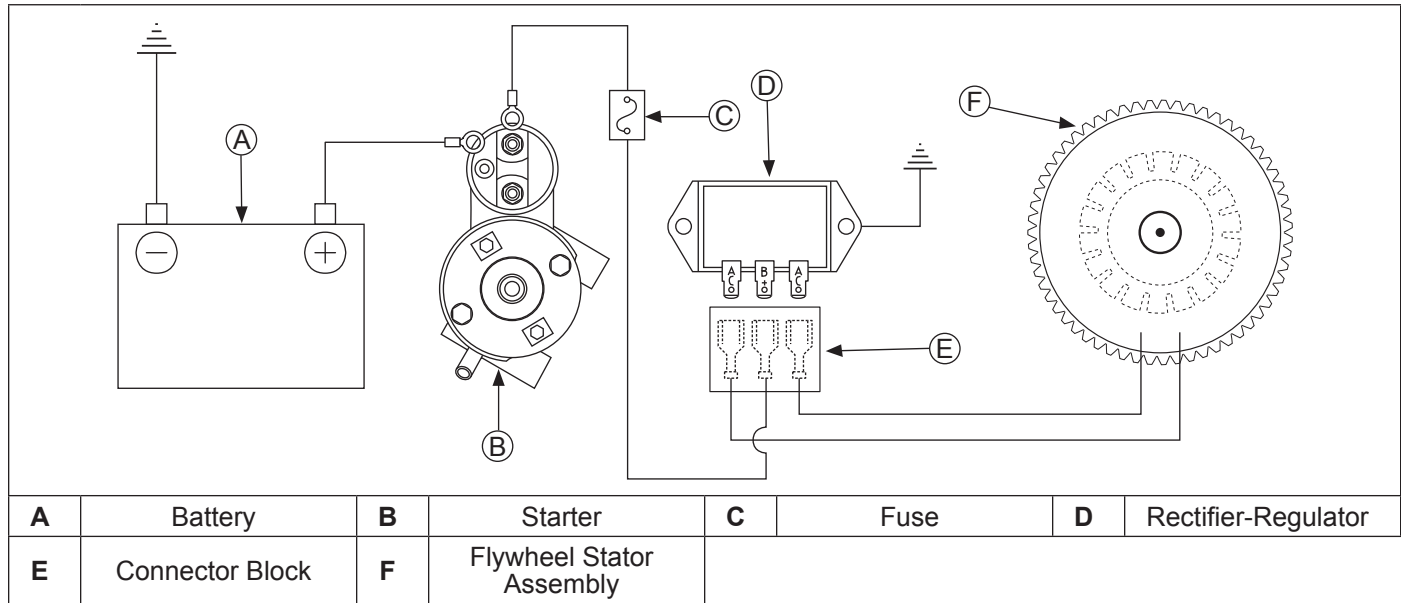
BATTERY CHARGING SYSTEM

NOTE: Observe following guidelines to avoid damage to electrical system and components:

- Make sure battery polarity is correct. A negative (–) ground system is used.
- Disconnect rectifier-regulator plug and/or wiring harness plug before doing any electric welding on equipment powered by engine. Also, disconnect all other electrical accessories in common ground with engine.
- Prevent stator (AC) leads from touching or shorting while engine is running. This could damage stator.

These engines are equipped with a 25 amp regulated charging system.

25 Amp Regulated Charging System



Stator

Stator is mounted on crankcase behind flywheel. Follow procedures in Disassembly/Inspection and Service and Reassembly if stator replacement is necessary.

Rectifier-Regulator

NOTE: When installing rectifier-regulator, take note of terminal markings and install plug(s) accordingly.

NOTE: Disconnect all electrical connections attached to rectifier-regulator. Testing may be performed with rectifier-regulator mounted or loose. Repeat applicable test procedure two or three times to determine condition of part.

NOTE: A flashing LOW light can also occur as a result of an inadequate ground lead connection. Make certain connection location is clean and clamp is secure.

Rectifier-regulator is mounted on blower housing. To replace, disconnect plug(s), remove mounting screws, and ground wire or metal grounding strap.

Testing rectifier-regulator may be performed as follows, using appropriate rectifier-regulator tester.

To test 25 amp rectifier-regulators:

1. Connect tester ground lead (with spring clamp) to body of rectifier-regulator.
2. Connect red lead from tester to middle terminal labeled B+.
3. Connect black leads from tester to both outer AC terminals on rectifier-regulator.
4. Plug tester into proper AC outlet/power supply for tester being used. Turn on power switch. POWER light should be illuminated and one of four status lights may be lit as well. This does not represent condition of part.
5. Press TEST button until a click is heard and then release. Momentarily one of four status lights will illuminate indicating partial condition of part.

Condition	Conclusion
	25 amp
OK (green) light comes on and stays steady.	Disconnect tester black lead attached to 1 AC terminal and reconnect it to other AC terminal. Repeat test. If OK (green) light comes on again, part is good and may be used.
NOTE: A flashing LOW light can also occur as a result of an inadequate ground lead connection. Make certain connection location is clean and clamp is secure. Other lights come on.	Rectifier-regulator is faulty and should not be used.

Electrical System

Troubleshooting Guide

25 Amp Battery Charging System

NOTE: Always zero ohmmeter on each scale before testing to ensure accurate readings. Voltage tests should be made with engine running at 3600 RPM - no load. Battery must be good and fully charged.

When problems occur in keeping battery charged or battery charges at too high a rate, problem can usually be found somewhere in charging system or with battery.

To test charging system for no charge to battery:

1. Insert an ammeter in B+ lead from rectifier-regulator. With engine running at 3600 RPM and B+ (at terminal on rectifier-regulator) to ground using a DC voltmeter.

If voltage is 13.8 volts or more, place a minimum load of 5 amps (turn on lights if 60 watts or more, or place a 2.5 ohm, 100 watt resistor across battery terminals) on battery to reduce voltage. Observe ammeter.

Condition	Conclusion
Charge rate increases when load is applied.	Charging system is OK and battery was fully charged.
Charge rate does not increase when load is applied.	Test stator and rectifier-regulator (steps 2 and 3).

2. Remove connector from rectifier-regulator. With engine running at 3600 RPM, measure AC voltage across stator leads using an AC voltmeter.

Condition	Conclusion
Voltage is 28 volts or more.	Stator is OK. Rectifier-regulator is faulty; replace.
Voltage is less than 28 volts.	Stator is faulty; replace. Test stator further using an ohmmeter (steps 3 and 4).

3. With engine stopped, measure resistance across stator leads using an ohmmeter.

Condition	Conclusion
Resistance is 0.1/0.2 ohms.	Stator is OK.
Resistance is 0 ohms.	Stator is shorted; replace.
Resistance is infinity ohms.	Stator is open; replace.

4. With engine stopped, measure resistance from each stator lead to ground using an ohmmeter.

Condition	Conclusion
Resistance is infinity ohms (no continuity).	Stator is OK (not shorted to ground).
Resistance (or continuity) measured.	Stator leads are shorted to ground; replace.

To test charging system for battery continuously charging at high rate:

1. With engine running at 3600 RPM, measure voltage from B+ lead to ground using a DC voltmeter.

Condition	Conclusion
Voltage is 14.7 volts or less.	Charging system is OK. Battery is unable to hold charge; service or replace.
Voltage is more than 14.7 volts.	Faulty rectifier-regulator; replace.

FUSES

This engine has three (3) blade type automotive fuses. Replacement fuses must have same rating as blown fuse. Use fuse chart below to determine correct fuse.

Wire Color	Fuse Rating
2 Purple Wires	30-amp Fuse
1 Red Wire w/ Black Stripe 1 Red Wire w/ White Stripe	10-amp Fuse
2 Red Wires	10-amp Fuse

Fuse Replacement

1. Shut engine off and remove key.
2. Locate fuse holders.
3. Remove fuse cover and pull out fuse.
4. Inspect fuse for a solid fusible link or a broken fusible link. Replace fuse if fusible link is broken. If you are not sure if fusible link is broken, replace fuse.
5. Insert fuse into fuse holder until it is seated properly. Install fuse cover.

ELECTRIC STARTING MOTOR

NOTE: Do not crank engine continuously for more than 10 seconds. Allow a 60 second cool down period between starting attempts. Failure to follow these guidelines can burn out starter motor.

NOTE: If engine develops sufficient speed to disengage starter but does not keep running (a false start), engine rotation must be allowed to come to a complete stop before attempting to restart engine. If starter is engaged while flywheel is rotating, starter pinion and flywheel ring gear may clash and damage starter.

NOTE: If starter does not crank engine, shut off starter immediately. Do not make further attempts to start engine until condition is corrected.

NOTE: Do not drop starter or strike starter frame. Doing so can damage starter.

Engines in this series use solenoid shift starters.

Operation-Solenoid Shift Starter

When power is applied to starter electric solenoid moves drive pinion out onto drive shaft and into mesh with flywheel ring gear. When pinion reaches end of drive shaft it rotates flywheel and cranks engine.

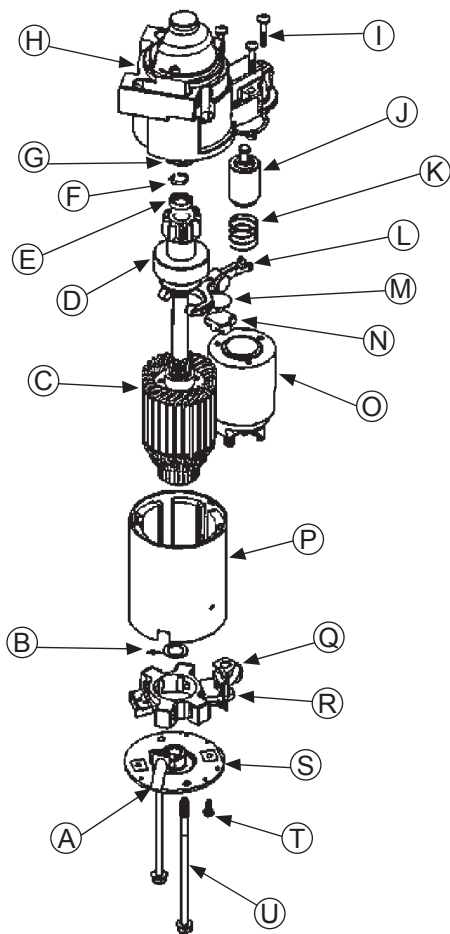
When engine starts and start switch is released, starter solenoid is deactivated, drive lever moves back, and drive pinion moves out of mesh with ring gear into retracted position.

Troubleshooting-Starting Difficulties

Condition	Possible Cause	Conclusion
Starter does not energize.	Battery	Check specific gravity of battery. If low, recharge or replace battery as necessary.
	Wiring	Clean corroded connections and tighten loose connections. Replace wires in poor condition and with frayed or broken insulation.
	Starter Switch or Solenoid	By-pass switch or solenoid with a jumper wire. If starter cranks normally, replace faulty components. Remove and perform individual solenoid test procedure.
Starter energizes but turns slowly.	Battery	Check specific gravity of battery. If low, recharge or replace battery as necessary.
	Brushes	Check for excessively dirty or worn brushes and commutator. Clean using a coarse cloth (not emery cloth). Replace brushes if excessively or unevenly worn.
	Transmission or Engine	Make sure clutch or transmission is disengaged or placed in neutral. This is especially important on equipment with hydrostatic drive. Transmission must be exactly in neutral to prevent resistance which could keep engine from starting. Check for seized engine components such as bearings, connecting rod, and piston.

Starter System

Solenoid Shift Starter Components



A	Tube	B	Washer
C	Armature	D	Drive
E	Stop	F	Retaining Ring
G	Collar	H	Drive End Cap
I	Screw	J	Plunger
K	Spring	L	Lever
M	Plate	N	Plug
O	Solenoid	P	Frame and Field
Q	Brush Holder	R	Nut
S	Commutator End Plate	T	Screw
U	Bolt		

Starter Disassembly

NOTE: Do not reuse old retainer.

NOTE: Do not soak armature or use solvent when cleaning. Wipe clean using a soft cloth, or use compressed air.

1. Remove hex nut and disconnect positive (+) brush lead/bracket from solenoid terminal.
2. Remove screws securing solenoid to starter.
3. Unhook plunger pin from drive lever. Remove gasket from recess in housing.

4. Remove thru (larger) bolts.
5. Remove commutator end plate assembly, containing brush holder, brushes, springs, and locking caps. Remove thrust washer from inside commutator end.
6. Remove frame from armature and drive end cap.
7. Remove drive lever pivot bushing and backing plate (if equipped) from end cap.
8. Take out drive lever and pull armature out of drive end cap.
9. Remove thrust washer from armature shaft.
10. Push stop collar down to expose retaining ring.
11. Remove retainer from armature shaft. Save stop collar.
12. Remove drive pinion assembly from armature.
13. Clean parts as required.

Inspection

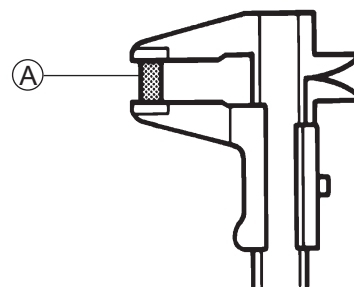
Drive Pinion

Check and inspect following areas:

- Pinion teeth for abnormal wear or damage.
- Surface between pinion and clutch mechanism for nicks or irregularities which could cause seal damage.
- Check drive clutch by holding clutch housing and rotating pinion. Pinion should rotate in only 1 direction.

Brushes and Springs

Detail

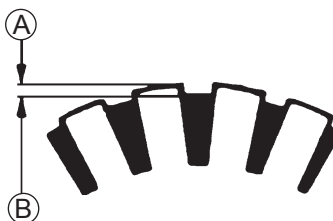


A	Wear Limit Length
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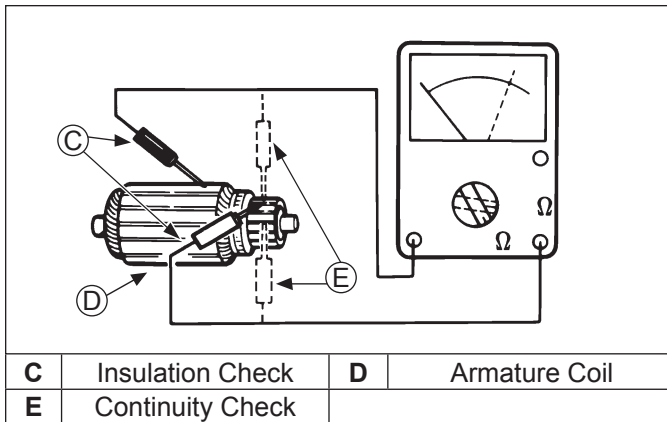
Inspect both springs and brushes for wear, fatigue, or damage. Measure length of each brush. Minimum length for each brush is 7.6 mm (0.300 in.). Replace brushes if they are worn, undersize, or condition is questionable.

Armature

Components and Details



A	Commutator O.D.	B	Mica Insulation
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1. Clean and inspect commutator (outer surface). Mica insulation must be lower than commutator bars (undercut) to ensure proper operation of commutator.
2. Use an ohmmeter set to Rx1 scale. Touch probes between 2 different segments of commutator, and check for continuity. Test all segments. Continuity must exist between all or armature is bad.
3. Check for continuity between armature coil segments and commutator segments. There should be no continuity. If continuity exists between any 2 armature is bad.
4. Check armature windings/insulation for shorting.

Shift Fork

Check that shift fork is complete, and pivot and contact areas are not excessively worn, cracked, or broken.

Brush Replacement

4 brushes and springs are serviced as a set. Use a new Kohler brush and spring kit if replacement is necessary.

1. Perform steps 1-5 in Starter Disassembly.
2. Remove screws securing brush holder assembly to end cap (plate). Note orientation for reassembly later. Discard old brush holder assembly.
3. Clean component parts as required.
New brushes and springs come preassembled in a brush holder with a protective sleeve that will also serve as an installation tool.
4. Perform steps 10-13 in Starter Reassembly sequence. If starter has been disassembled, installation must be done after armature, drive lever, and frame are installed.

Starter Reassembly

NOTE: Always use a new retainer. Do not reuse old retainers that have been removed.

NOTE: Correctly installed, center pivot section of drive lever will be flush or below machined surface of housing.

1. Apply drive lubricant to armature shaft splines. Install drive pinion onto armature shaft.
2. Install and assemble stop collar/retainer assembly.
 - a. Install stop collar down onto armature shaft with counter bore (recess) up.

- b. Install a new retainer in larger (rear) groove of armature shaft. Squeeze with a pliers to compress it in groove.
 - c. Slide stop collar up and lock it into place, so recess surrounds retainer in groove. If necessary, rotate pinion outward on armature splines against retainer to help seat collar around retainer.
3. Install offset thrust (stop) washer so smaller offset of washer faces retainer/collar.
 4. Apply a small amount of oil to bearing in drive end cap, and install armature with drive pinion.
 5. Lubricate fork end and center pivot of drive lever with drive lubricant. Position fork end into space between captured washer and rear of pinion.
 6. Slide armature into drive end cap and at same time seat drive lever into housing.
 7. Install rubber grommet into matching recess of drive end cap. Molded recesses in grommet should be out, matching and aligned with those in end cap.
 8. Install frame, with small notch forward, onto armature and drive end cap. Align notch with corresponding section in rubber grommet. Install drain tube in rear cutout, if it was removed previously.
 9. Install flat thrust washer onto commutator end of armature shaft.
 10. Starter reassembly when replacing brushes/brush holder assembly:
 - a. Hold starter assembly vertically on end housing, and carefully position assembled brush holder assembly, with supplied protective tube, against end of commutator/armature. Mounting screw holes in metal clips must be up/out. Slide brush holder assembly down into place around commutator, and install positive (+) brush lead grommet in cutout of frame. Protective tube may be saved and used for future servicing.
- Starter reassembly when not replacing brushes/brush holder assembly:
- a. Carefully unhook retaining caps from brush assemblies. Do not lose springs.
 - b. Position brushes back in their slots so they are flush with I.D. of brush holder assembly. Insert brush installation tool (with extension), or use tube described above from a prior brush installation, through brush holder assembly, so holes in metal mounting clips are up/out.
 - c. Install brush springs and snap on retainer caps.
 - d. Hold starter assembly vertically on end housing, and carefully place tool (with extension) and assembled original brush holder assembly onto end of armature shaft. Slide brush holder assembly down into place around commutator, install positive (+) brush lead grommet in cutout of frame.
11. Install end cap onto armature and frame, aligning thin raised rib in end cap with corresponding slot in grommet of positive (+) brush lead.

Starter System

12. Install thru bolts and brush holder mounting screws. Torque bolts to 5.6-9.0 N·m (49-79 in. lb.) and brush holder mounting screws to 2.5-3.3 N·m (22-29 in. lb.).
13. Hook plunger behind upper end of drive lever and install spring into solenoid. Insert mounting screws through holes in drive end cap. Use these to hold solenoid gasket in position, then mount solenoid. Torque screws to 4.0-6.0 N·m (35-53 in. lb.).
14. Connect positive (+) brush lead/bracket to solenoid and secure with nut. Torque nut to 8-11 N·m (71-97 in. lb.). Do not overtighten.

Solenoid Tests

NOTE: DO NOT leave 12 volt test leads connected to solenoid for any time over what is necessary for performing each of individual tests. Internal damage to solenoid may occur.

Disconnect all leads from solenoid including positive brush lead attached to lower stud terminal. Remove mounting hardware and separate solenoid from starter for testing.

To test solenoid pull-in coil/plunger:

Actuation

1. Use a 12 volt power supply and 2 test leads.
2. Connect 1 lead to flat spade S/start terminal on solenoid. Momentarily connect other lead to lower large post terminal.
When connection is made solenoid should energize (audible click) and plunger retract. Repeat test several times.

Continuity

1. Use an ohmmeter set to audible or Rx2K scale, and connect 2 ohmmeter leads to 2 large post terminals.
2. Perform solenoid pull-in coil/plunger actuation test and check for continuity. Ohmmeter should indicate continuity. Repeat test several times.

To test solenoid hold-in coil:


Function

1. Connect a 12 volt test lead to flat spade S/start terminal on solenoid and other lead to body or mounting surface of solenoid.
2. Manually push plunger IN and check if coil holds plunger retracted. Do not allow test leads to remain connected to solenoid for a prolonged period of time.

Continuity

1. Use an ohmmeter set to audible or Rx2K scale, and connect 2 ohmmeter leads to 2 large post terminals.
2. Perform preceding solenoid hold-in coil function test and check for continuity. Meter should indicate continuity. Repeat test several times.

Condition	Conclusion
Solenoid fails to activate.	Replace solenoid.
No continuity is indicated.	
Plunger fails to stay retracted.	

	<p>⚠ WARNING</p> <p>Hot liquid can cause severe burns.</p> <p>Do not loosen radiator cap while engine is operating or warm to touch.</p>	<p>Liquid coolant can get extremely hot from operation. Turning radiator cap when engine is hot can allow steam and scalding liquid to blow out and burn you severely. Shut off machine. Only remove radiator cap when cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing completely.</p>
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When it is necessary to open cooling system at radiator cap, shut off engine and remove filler cap only when cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing completely.

This section covers operation and servicing of liquid cooling system.

Cooling System Components

Cooling system consists of these following components:

- Radiator with removable screen
- Hoses
- Coolant Pump and Belt
- Thermostat
- Intake Manifold with Thermostat Housing
- Radiator Cap
- Cooling Fan, Belt, and Drive Pulleys
- Overflow Reservoir
- Crankcase and Heads with Integral Cooling Passages

Operation

Engine coolant is pumped through cooling system by a pump, belt-driven off camshaft. Coolant coming out of pump is divided, and moves simultaneously through separate circuits within each head and corresponding sides of crankcase. As coolant moves through these passages, it absorbs heat from engine parts. After traveling through engine, coolant from two separate circuits merges and moves through intake manifold to lower side of thermostat. During warm-up, thermostat is closed, preventing circulation through radiator. Coolant circulates through engine only and is returned to pump via bypass hose. When engine heat brings coolant up to a temperature of 79.4°C (175°F), thermostat will begin to open, allowing coolant to circulate through upper hose to radiator. Thermostat is completely open at 90.5°C (195°F) allowing full coolant flow through radiator, where it is cooled. After getting cooled in radiator, coolant is drawn into pump through lower radiator hose and circulation starts all over again. A cooling fan, driven off flywheel by a belt, draws ambient air through radiator, to maintain cooling process.

Coolant will provide protection from -37°C (-34°F) to 108°C (226°F). For protection and use outside indicated temperature limits, follow antifreeze manufacturer's instructions on container, but do not exceed 70% antifreeze.

DO NOT use antifreeze with stop-leak additive(s), or put any other additives in cooling system.

Cooling System Maintenance and Service

Maintenance

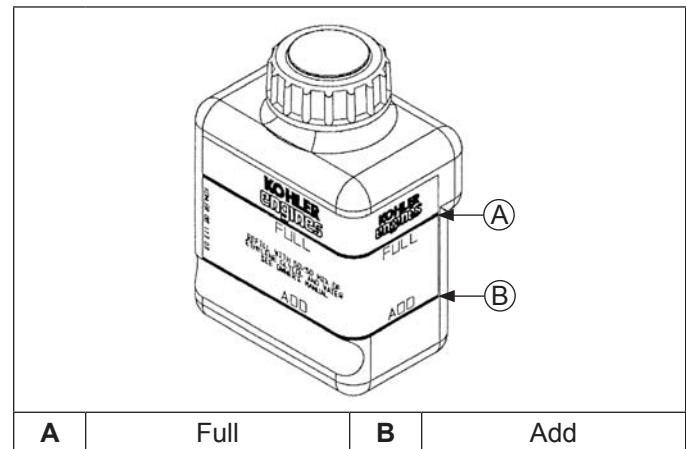
Maintaining correct coolant level, cleaning any debris accumulation from radiator surfaces, and insuring all parts are in proper operating condition, is critical to ensuring long life, proper system performance and preventing overheating. To ensure proper air circulation, make sure radiator, cooling fan, drive belt, pulleys, cooling fins, and external surfaces of engine are kept clean and in good condition at all times. Check coolant level and clean away any debris accumulation daily or before each use. Simultaneously inspect hoses and all system connections for signs of leakage. Make sure cooling fan is not cracked or missing any blades. Check that fan belt and two drive pulleys, are in good condition and proper belt tension is present.

Service

Lift screen vertically to remove for cleaning/servicing. Clean screen and cooling fins of radiator with a soft brush or blow out using clean compressed air. To avoid damage to screen and cooling fins, do not use a high pressure washer to clean.

Checking Coolant Level

Overflow Reservoir Details



NOTE: Do not operate engine without coolant in system. Do not remove radiator cap when hot. Engine coolant is hot and under pressure and can cause severe burns. To prevent engine overheating and damage, do not exceed more than 70% antifreeze in cooling system.

Coolant level should be checked at overflow reservoir, located behind radiator on fan shroud.

1. Check coolant level within overflow reservoir. Coolant level should be between FULL and ADD marks on reservoir. Do not operate engine with

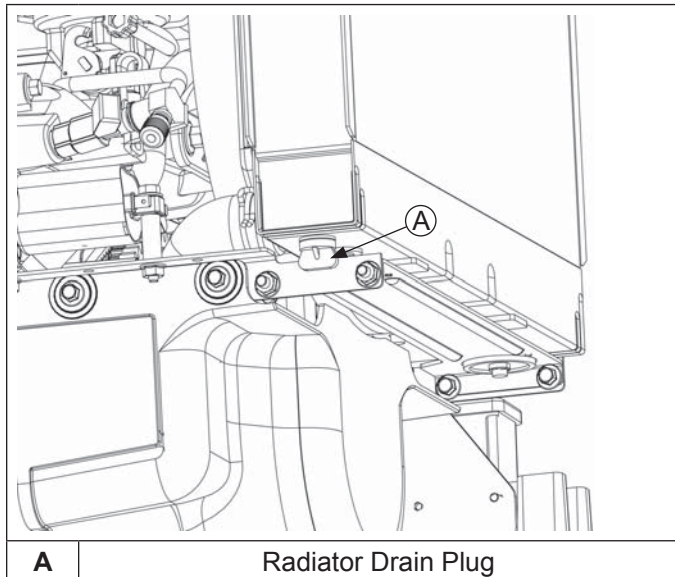
Cooling System

coolant level below ADD mark.

Add coolant to overflow reservoir as required, which is a 50/50 mixture of ethylene glycol and water (distilled or deionized water is recommended).

Drain Cooling System

Radiator Drain Plug Details



1. Ensure engine is cool. When radiator is cool to touch, slowly loosen radiator cap to first stop and allow any pressure to bleed off. Then loosen it fully and remove it.
Loosen/remove radiator drain plug and allow coolant to drain.
2. If equipped, remove coolant drain plugs located on each side of engine block. Drain coolant into a suitable container. After coolant has drained completely, apply pipe sealant with Teflon® (Loctite® PST® 592™ or equivalent), to threads and reinstall plugs. Torque plugs to 36.7 N·m (325 in. lb.).
3. Remove overflow hose from reservoir. Unhook inboard retainer and slide reservoir out of supports. Pour out contents and wash or clean as required. Dispose of all old coolant in accordance with local ordinances.
4. Reinstall reservoir cap. Do not kink/pinch hose.
5. Flush cooling system.

Flushing Cooling System

NOTE: To prevent engine damage, do not pour water into a hot engine. Do not operate engine without coolant.

With system properly drained:

1. Fill cooling system with clean water and a cooling system cleaner recommended for aluminum engines. Follow directions on container.
2. Reinstall and tighten radiator cap.
3. Start and run engine for five minutes, or until it reaches operating temperature. Stop engine and allow it to cool.

4. Drain cooling system.
5. Fill cooling system.

Filling Cooling System

NOTE: To prevent engine damage, do not use antifreeze mixture greater than 70% ethylene glycol in cooling system. Do not use antifreeze with stop-leak additive(s) or mix/add other additives to cooling system. Use only ethylene glycol antifreeze.

Cooling system capacity is approximately 2 liters (2.18 qt.).

1. Check condition of cooling system hoses, clamps, and associated components. Replace as required.
2. Fill with 2.0 L (2.1 U.S. qt.) equal parts of ethylene glycol (anti-freeze) and water only. Distilled or deionized water is recommended, especially in areas where water contains a high mineral content. Propylene glycol based anti-freeze is not recommended.
3. Fill radiator with coolant mixture. Allow coolant to drain into lower areas. Fill overflow reservoir to a level between FULL and ADD marks. Reinstall radiator and reservoir caps.
4. Start and run engine for five minutes. Stop engine and allow to cool.
5. Recheck coolant level in reservoir. Coolant level should be between FULL and ADD marks. Add coolant to reservoir if required.

Inspection

Cooling Fan Assembly, Belt, and Drive Pulleys

Cooling fan assembly, used to draw air through radiator, is attached to a hub and pulley assembly with sealed ball bearings. This assembly is belt driven off flywheel, via a lower split pulley, and requires very little service or maintenance. DO NOT operate engine without fan and properly functioning cooling system or engine damage will occur.

1. Inspect fan for any cracks, damaged/missing fan blades, and secure mounting.
2. Bearings in hub of pulley should rotate smoothly, without roughness, binding, or play/wobble.
3. V-groove of each pulley (upper and lower) should not be bent, nicked, or damaged. Pulley mounting areas and lower pulley shims should be free of any cracks or elongation.
4. Drive belt is designed and constructed for this system. Do not use a substitute belt. Check overall condition and replace belt if cracked, damaged, or proper tension cannot be established by repositioning of lower pulley shims. Use only Kohler Part No. 66 203 02-S belt if replacement is necessary.

See a Kohler authorized dealer for any necessary service.

Checking Fan Belt and Tension

Fan belt and belt tension should be checked daily or before each use. Fan belt should not be cracked, damaged, or exhibit excessive wear. Proper tension is 12.7 mm (3/8 - 1/2 in.) belt deflection per side under 10 lbs. applied tension.

If belt is cracked, damaged, or is worn that relocation of pulley shims cannot establish proper belt tension, belt should be replaced. Use only Kohler Part No. 66 203 02-S belt. DO NOT use a substitute belt.

For a new belt, assemble lower pulley with all three shims between pulley halves. For a used/original belt being reinstalled, assemble with two or one shim(s) between pulley halves and remaining shim(s) on outside (front) of outer pulley half. Check belt tension as described above.

When proper tension is obtained, individually remove each capscrew of lower pulley, apply Loctite® 242® to threads, and reinstall. Torque each capscrew in a criss-cross sequence to 24.5 N·m (215 in. lb.).

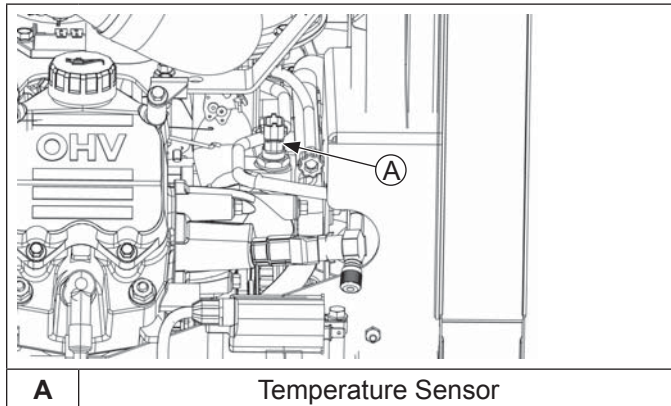
Hoses and Tubes

Hoses and tubes are used to connect components within cooling system. To guard against coolant loss and hose failure, hoses, tubes and their connections should be checked regularly for leaks or damage. Loss of coolant can result in serious engine damage. Over time, engine vibration can affect hose/joint connections, and hoses themselves can be affected by heat and coolant. Swelling, hardening, and/or deterioration can occur depending on operating environment. Deterioration usually takes place more rapidly from inside, making outside inspections incomplete and not always dependable. Regular outside inspection and careful inside inspection whenever connections are opened, can minimize a possible in-service problem.

Use new clamps whenever a hose is replaced or a joint connection is opened. When making hose connections, a light coating of rubber lubricant will make assembly easier.

Thermostat Testing and Servicing

Temperature Sensor Details



Thermostat is mounted in intake manifold, beneath thermostat housing. It controls rapid warm-up and operating temperature of engine. If a problem is encountered which is thought to be fault of thermostat, it can be checked to determine its operating condition. Before removing and testing thermostat, make sure all other possible causes such as debris accumulation/obstruction, leaks, belt or fan failure, coolant level, and damaged components are eliminated as possible causes.

To Test

Remove thermostat from system. Hang or suspend thermostat by its frame in a container of water, so thermostat does not touch bottom of container. Heat water and measure temperature (an oven thermometer can be used). Spring-loaded valve of thermostat should begin to open at 79.4°C (175°F), and can be completely open at 90°C (195°F). If valve opens at a temperature more than 10 degrees below specified opening or fails to open at a temperature 10 to 15 degrees above specified opening, thermostat should be replaced. If valve in thermostat can be moved or pushed off its seat with a slight effort when thermostat is cold, unit may be considered defective and should be replaced. Thermostat should be replaced if operation is found to be questionable or faulty.

Installation

1. Thoroughly clean sealing surfaces of intake manifold and thermostat housing with an aerosol gasket remover. Make sure sealing surfaces are clean and free of nicks or damage. Make sure notch in intake manifold is clean.
2. Install a new thermostat into intake manifold, so larger spring end is down into well of intake manifold. Position a new thermostat gasket on intake manifold.
3. Install thermostat housing onto intake manifold.
4. Install and torque screws to 9.9 N·m (88 in. lb.).
5. Reconnect radiator hose and secure with hose clamp, if separated previously.

High Temperature Sensor

A high temperature sensor may be mounted in intake manifold and is used to activate a warning light, audible alarm, or kill engine (depending on application), if safe operating temperature is exceeded. Sensor is a normally open switch which completes a circuit, when coolant temperature reaches rated temperature limit of switch. For these engines temperature sensor limit is 123.8°C (255°F).

If warning device activates, or engine kills, indicating an excessive operating temperature, check following:

1. Make sure fan belt is in good condition and properly tensioned.
2. Make sure cooling fan is properly secured, not broken, damaged, or missing blades.
3. Make sure all air intake and cooling surfaces are clean and free of debris accumulation.
4. After engine has sufficiently cooled, check coolant level in system to make sure it is not low, or improperly mixed.
5. Check cooling system for leaks.

Cooling System

6. Check thermostat, and pressure test radiator cap.
7. Make sure water pump and drive belt are operational.
8. Check and inspect wiring from sensor for shorting or damage.

If none of those are found to be cause do following:

1. Drain coolant from system, so level is lower than installed position of temperature sensor.
2. Remove and replace temperature sensor. Use pipe sealant with Teflon® on threads.

Cooling System Leakage Test

A pressure test of cooling system can be performed as a relatively simple means of determining whether cooling system may contain a leak. A pump/pressure type cooling system tester with appropriate 45 mm adapter may be used to check cooling system and radiator cap.

Test Instructions

1. With engine cool, carefully remove radiator cap (see Pressure Radiator Cap). Make sure all parts of cap and adapter are clean. Install cap on corresponding adapter and make sure it is completely seated. Install adapter onto tester and lock in place.
2. Pressurize tester to 15 psi.
3. Observe indicated pressure. It should hold steady and not decrease or leak down.
If leakage is detected, cap should be replaced. If tester pressure is increased to 16 psi, or above, cap should then bleed off this excess pressure.
4. Install and lock system adapter and tester onto neck of cooling system. Pressurize tester to 14-15 psi.
5. Observe system pressure on gauge.

Gauge Needle Holds Steady

If gauge needle holds steady, there should be no serious leaks in system. It is however, recommended that all connections be checked for overall condition anyway, using a flashlight.

Gauge Needle Drops Slowly

If gauge needle drops slowly it indicates presence of a small leak or seepage. Check all components and connections for signs of leakage. Check condition of radiator hoses. If they swell excessively while testing system, they may be weak and should be replaced.


Gauge Needle Drops Quickly

A steady drop or loss of pressure indicates serious leakage is occurring within system, which must be located and corrected before engine is returned to service.

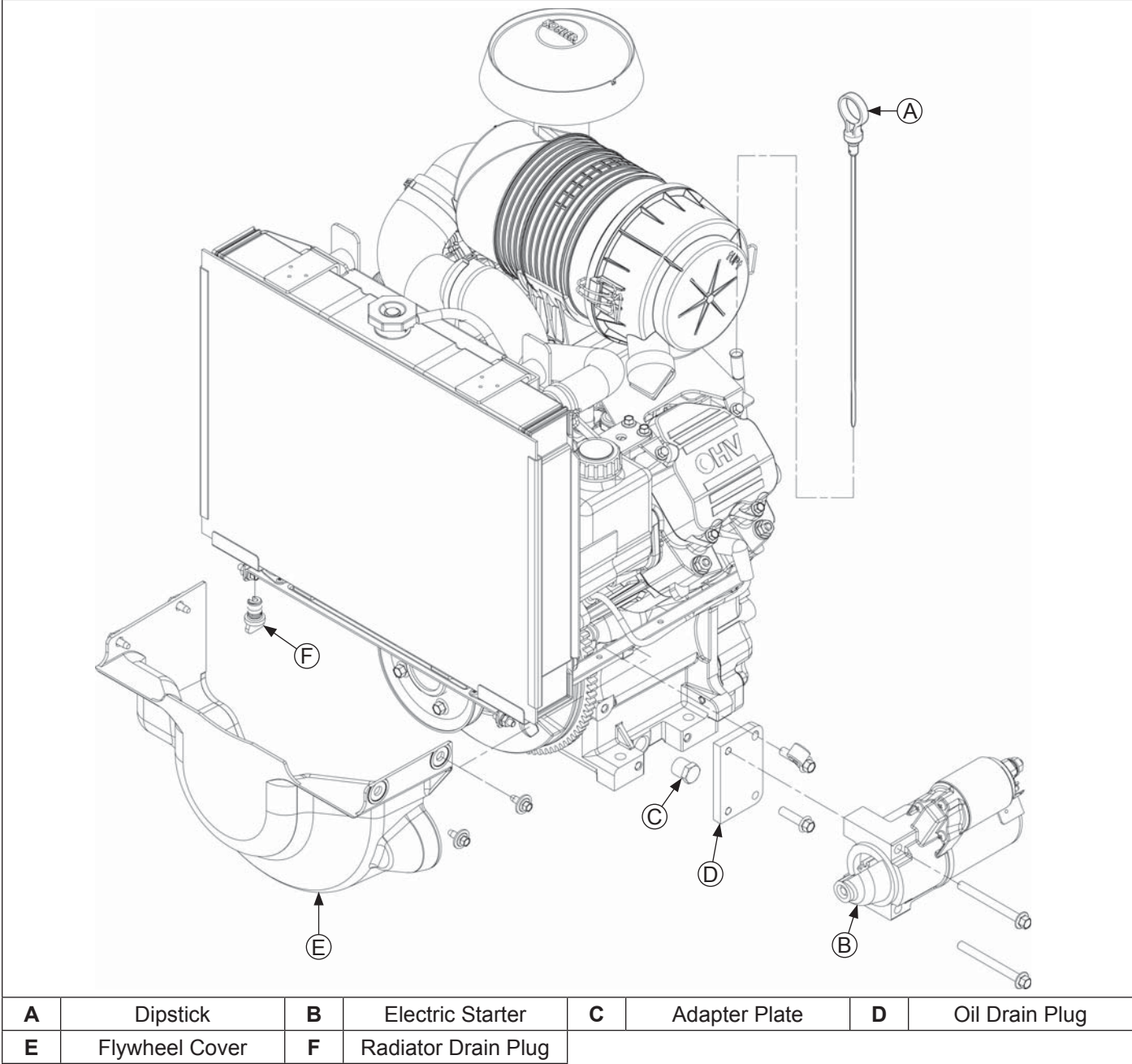
If a pressure loss is noted:

1. With pressure on system, apply a soap/water solution and check all joint connections, hoses, and cooling system components for external leakage. Repair or replace as required.

2. Remove dipstick and check appearance of oil in crankcase. Another method would be to remove an oil drain plug and drain a small amount of oil for inspection. A milky or an opaque color, similar to chocolate milk, indicates presence of engine coolant in oil. Check for a blown head gasket (step 3 below) or a possible crack or internal leakage from water jacket.
3. Remove spark plugs. Apply 14-15 lbs. of pressure and listen/inspect for internal coolant leakage into cylinder/combustion chambers. This can denote a head gasket failure/leak. If required, further test by performing a Cylinder Leakdown Test as described in Troubleshooting.

	⚠ WARNING	Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug lead(s). 2) Disconnect negative (-) battery cable from battery.
	Accidental Starts can cause severe injury or death. Disconnect and ground spark plug lead(s) before servicing.	

External Engine Components



Disassembly/Inspection and Service

Clean all parts thoroughly as engine is disassembled. Only clean parts can be accurately inspected and gauged for wear or damage. There are many commercially available cleaners that will quickly remove grease, oil, and grime from engine parts. When such a cleaner is used, follow manufacturer's instructions and safety precautions carefully.

Make sure all traces of cleaner are removed before engine is reassembled and placed into operation. Even small amounts of these cleaners can quickly break down lubricating properties of engine oil.

Disconnect Spark Plug Leads

NOTE: Pull on boot only, to prevent damage to spark plug lead.

1. Disconnect leads from spark plugs.

Shut Off Fuel Supply

Remove Muffler

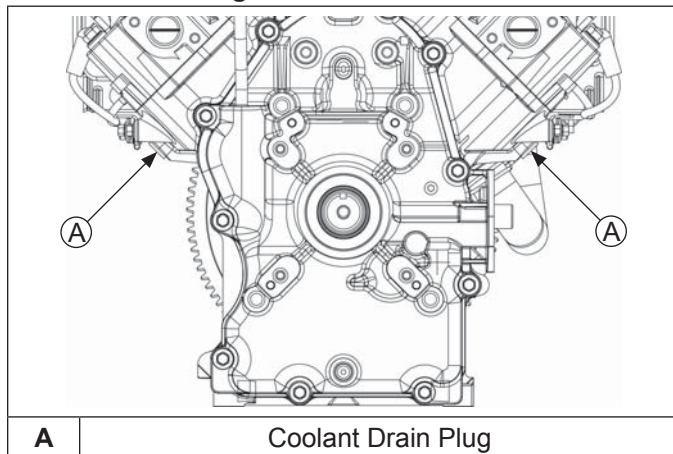
1. Remove exhaust system, muffler, and attaching hardware from engine.

Remove Starter and Adapter Plate

1. Disconnect leads attached to starter solenoid terminals.
2. Remove screws securing starter to adapter plate.
3. Remove screws attaching adapter to crankcase. Note orientation of cutout. Upper screw may also secure a clamp for stator leads.

Drain Coolant from Cooling System

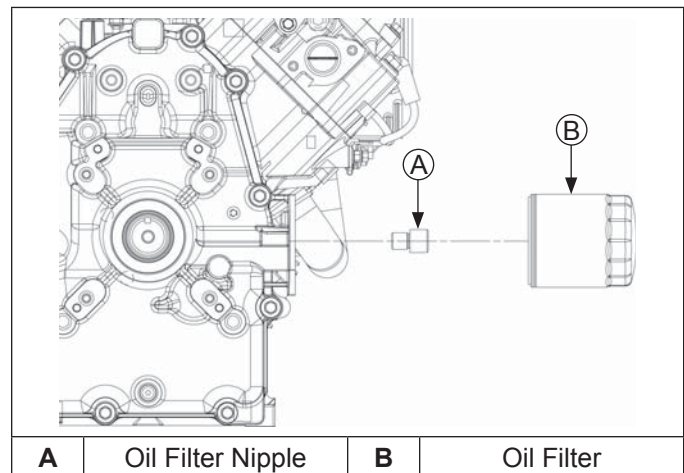
Coolant Drain Plug Details



1. Loosen radiator cap, then loosen radiator drain plug and allow system to drain. Use a suitable container to catch coolant.
2. If equipped, remove coolant drain plugs on each side of block. Allow any remaining coolant to drain out. Dispose of coolant properly, according to local regulations.

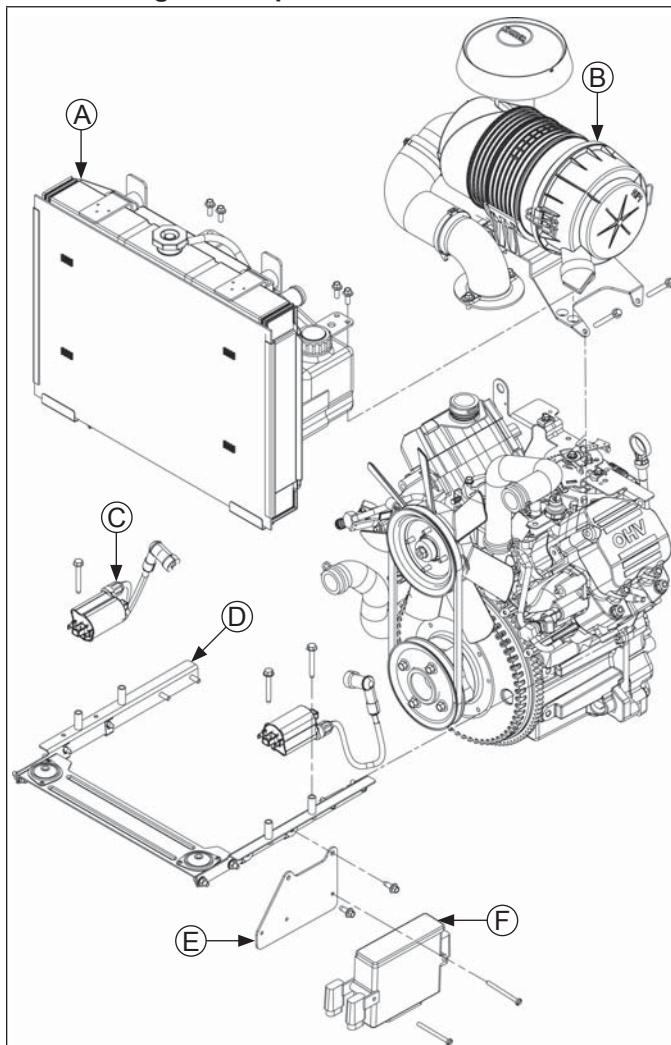
Drain Oil from Crankcase and Remove Oil Filter

Oil Filter Details



1. Remove oil fill cap and dipstick, and one or both drain plugs. Allow sufficient time for oil to drain out.
2. Remove and discard oil filter.

External Engine Components



A	Radiator Assembly	B	Air Cleaner Assembly
C	Ignition Module	D	Mounting Bracket
E	Adapter Plate	F	ECU

Remove ECU and Ignition Modules

1. Disconnect wire harness from ECU, and remove screws securing adapter plate.
2. Disconnect wire lead from ignition modules, and remove screws securing ignition modules. Retain spacers for reassembly.

Remove Flywheel Cover, Radiator Assembly, Mounting Brackets and Attached Components

NOTE: Do not allow cooling fins of radiator to contact fan blades.

1. Remove screws or nuts and flat washers (2 on each side) securing lower flywheel cover to LH and RH radiator support brackets. Mounting plate for rectifier-regulator will become detached when LH screws are removed. Do not lose small spacers located within holes of lower cover. Clips are used on some models instead of nuts.

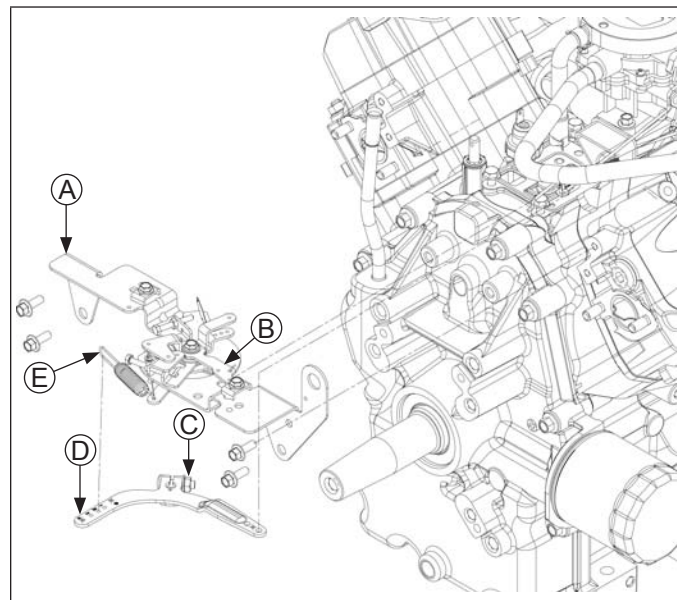
2. Disconnect upper radiator hose from radiator, and lower radiator hose from inlet of water pump.
3. Remove screws securing two upper radiator supports to air cleaner mounting bracket.
4. Carefully tilt (pull) radiator forward slightly to clear fan and lift complete assembly out of lower mounting bracket.
5. Remove four screws securing LH and RH side mounting brackets to crankcase. Pull complete mount assembly forward to remove.
6. Further disassembly for component servicing may be performed as required.

Remove Air Cleaner Assembly

1. Remove screws securing elbow adapter and gasket to intake manifold.
2. Disconnect breather hose from intake manifold.
3. Remove upper valve cover mounting screws on each side, which also secure main mounting bracket for air cleaner.
4. Disconnect connector plug from rectifier-regulator. Remove screw securing rectifier-regulator ground wire to intake manifold. Rectifier-regulator can remain secured to bracket.
5. Lift air cleaner/mounting bracket assembly off engine.

Remove Throttle and Choke Controls

Control Panel Details



A	Control Panel	B	Choke Lever
C	Governor Lever Nut	D	Governor Lever
E	Governor Spring		

1. Remove screws securing main control bracket to cylinder heads.
2. Mark hole location and disconnect governor spring from governor lever.

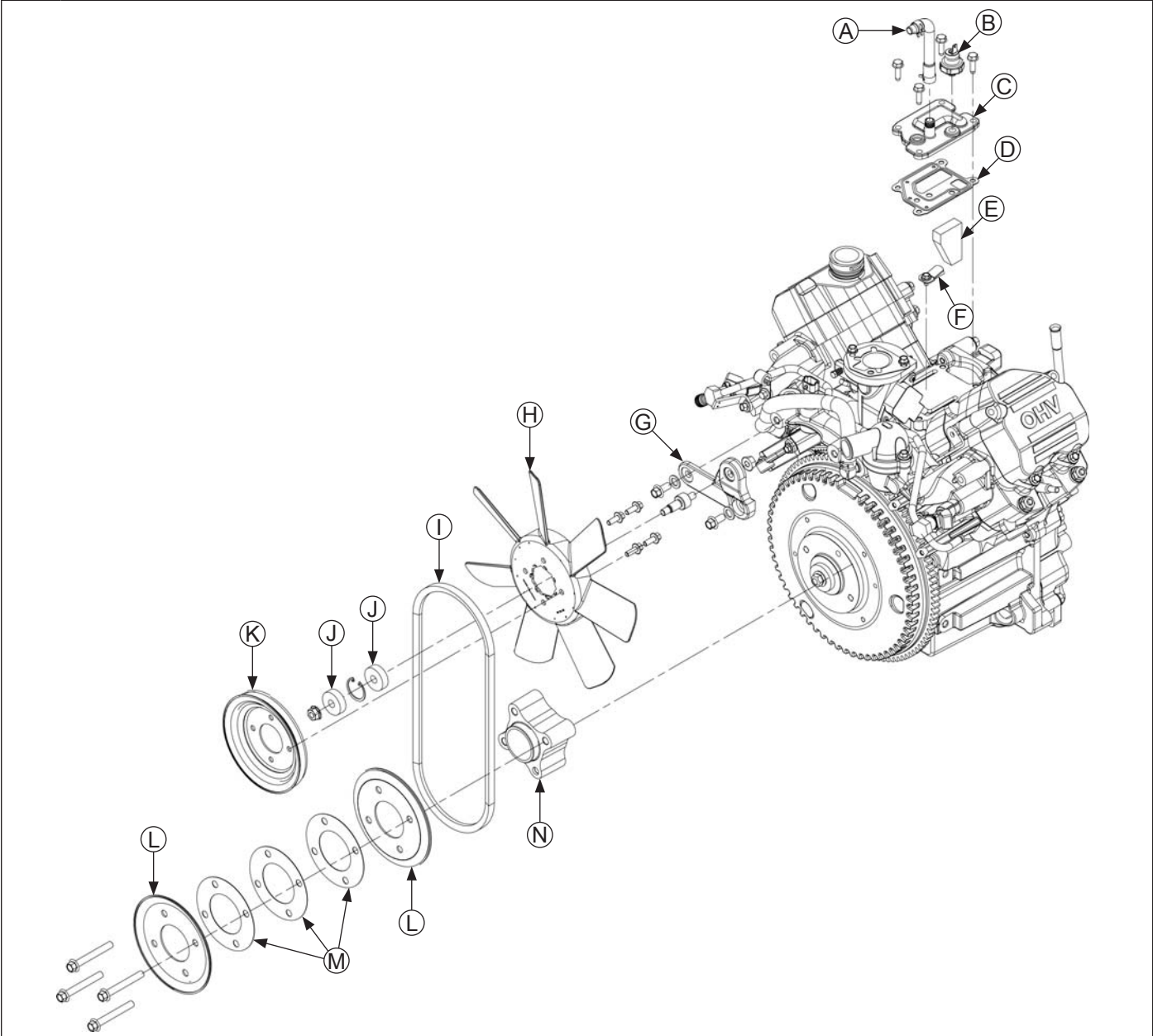
Disassembly/Inspection and Service

- 3. Tilt main bracket and disconnect choke linkage from choke lever. Remove main control bracket.
- 4. Unhook choke linkage from actuator lever on intake manifold.

Remove External Governor Controls

- 1. Loosen nut of governor lever mounting screw. Leave throttle linkage and spring connected to lever. Lift governor lever off governor shaft and lay assembly on top of crankcase, to be removed with intake manifold.

External Engine Components



A	Breather Hose	B	Oil Sentry™	C	Breather Cover	D	Gasket
E	Fiber Filter	F	Breather Reed Assembly	G	Fan Mounting Bracket	H	Fan
I	Fan Belt	J	Bearing	K	Pulley	L	Pulley Half
M	Spacer Shims	N	Adapter				

Remove Oil Sentry™ (If So Equipped)

1. Disconnect wire lead from Oil Sentry™ switch, and remove switch from breather cover.

Remove Breather Cover

1. Remove screws securing breather cover to crankcase.
2. Carefully pry under protruding edge of breather cover to separate and remove cover from gasket.
Do not pry on sealing surfaces as it could cause damage resulting in leaks.
3. Remove breather gasket and fiber filter from breather chamber.
4. Remove screw, breather reed retainer and breather reed from breather chamber.

Remove Lower Drive Pulley and Fan Belt

1. Remove four screws attaching lower drive pulley assembly to pulley adapter and flywheel.
2. Remove pulley halves with spacer shims from adapter, and take fan belt off upper pulley/fan assembly. Note number of shims between pulley halves, and on front side of pulley, especially if same belt will be reinstalled.

Remove Fan Assembly, Mounting Bracket, and Fan Shaft

NOTE: Further disassembly of fan/hub and pulley assembly is not necessary unless a problem exists; see. If disassembly is performed, note assembly order and position of parts.

1. Remove front nut and washer securing fan assembly to fan shaft. Remove fan and pulley assembly from upper mounting bracket.
2. Remove screws and take off mounting bracket, with fan shaft attached.
3. Fan shaft may be removed from mounting bracket, by removing rear nut, if individual servicing of either part is required.

Inspection and Service

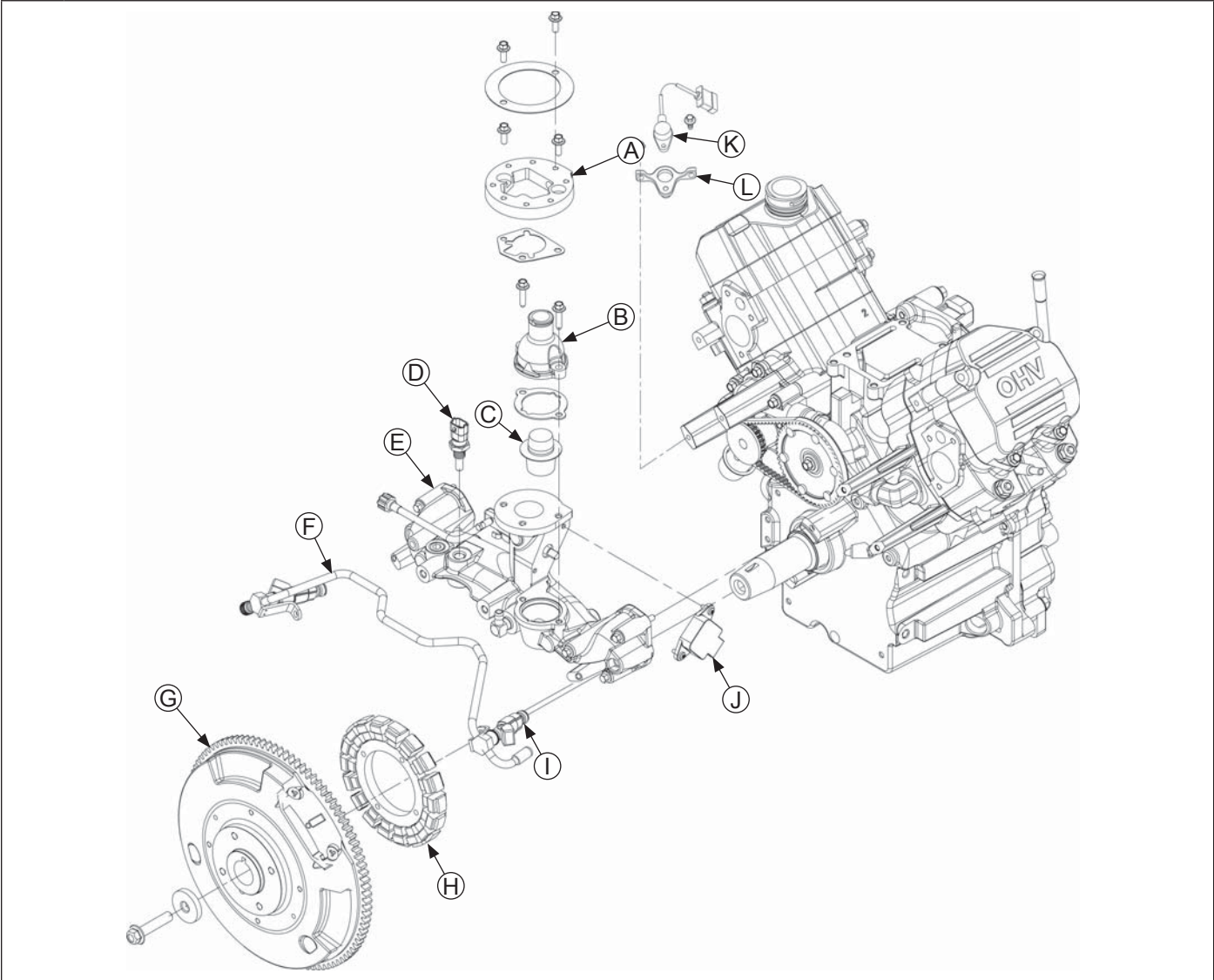
Cooling fan assembly consists of a fan attached to a v-pulley and bearing carrier (hub), rotating on a dual ball-bearing fan shaft (arbor). Assembly is mounted with a bracket to intake manifold and driven via a split pulley off flywheel.

Inspect components carefully for signs of wear or damage.

1. Inspect fan to make sure blades are in good condition and free of any cracks, nicks, or damage. Area around fan mounting holes must also be free of any cracks or damage.
2. Fan and hub assembly, when mounted to center arbor shaft, must rotate smoothly without noticeable bearing play, wobble, or binding.
3. Check v-belt for excessive wear, cracking or damage. If proper belt tension cannot be obtained, or condition of belt is suspect; replace it with Kohler Part No. 66 203 02-S. Do not use a substitute belt.

Disassembly/Inspection and Service

Flywheel/Ignition/Intake Manifold Components



A	Adapter	B	Thermostat Housing	C	Thermostat	D	Engine (Coolant) Temperature Sensor
E	Fuel Rail	F	Intake Manifold	G	Flywheel	H	Stator
I	Fuel Injector	J	Throttle Position Sensor	K	Speed Sensor	L	Speed Sensor Bracket

Remove Speed Sensor

1. Disconnect speed sensor connector.
2. Remove screws securing speed sensor bracket.

Remove Flywheel

NOTE: Always use a flywheel puller to remove flywheel from crankshaft. Do not strike crankshaft or flywheel, as these parts could become cracked or damaged.

1. Use a flywheel strap wrench or holding tool to hold flywheel. Remove screw and flat washer.
2. Use a puller to remove flywheel from crankshaft.
3. Remove woodruff key from crankshaft keyway.

Inspection

Inspect flywheel for cracks, and flywheel keyway for damage. Replace flywheel if cracked. Replace flywheel, crankshaft, and key if flywheel key is sheared or keyway is damaged.

Inspect ring gear for cracks or damage. Kohler does not provide ring gears as a serviceable part. Replace flywheel if ring gear is damaged.

Check charging system magnets to be sure they are not loose or cracked.

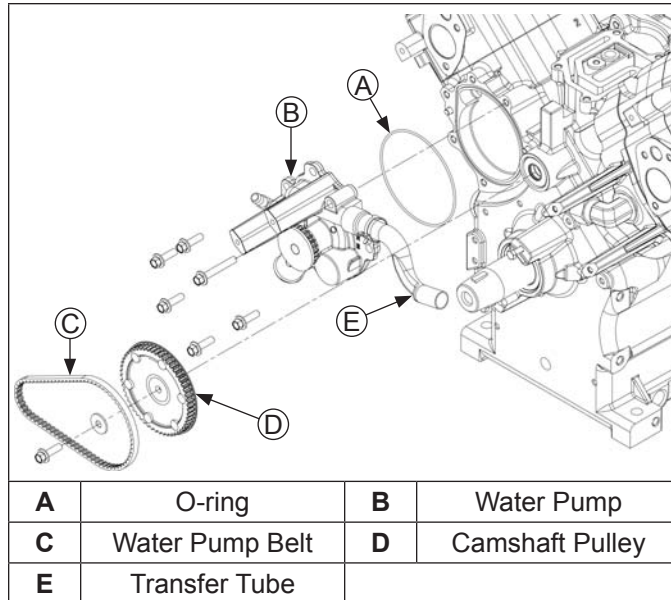
Remove Stator Assembly

1. Remove mounting screws, and pull stator, with plug-in connector attached, from engine.

Remove Intake Manifold, Thermostat Housing, Bypass Hose and Wiring Harness

1. Disconnect by-pass hose from fitting on water pump.
2. Remove six mounting screws and carefully separate intake manifold from cylinder heads, with by-pass hose and wiring harness attached.
3. Remove intake manifold gaskets.
4. Further disassembly of intake manifold components may be performed as necessary. If thermostat is to be removed, loosen and remove screws securing thermostat housing to intake manifold. Separate housing and remove thermostat, discard old gasket. O-rings and retaining clips should be replaced any time fuel injector is separated from its normal mounting position.

Water Pump Components



Remove Camshaft Pulley and Water Pump Belt

1. Remove screw and flat washer, securing cogged drive pulley to camshaft.
2. Carefully lift pulley off camshaft and remove belt from water pump pulley.
3. Remove camshaft key from keyway.

Remove Water Pump and Transfer Tube

1. Loosen and unscrew hex cap section securing transfer tube to 90° fitting in crankcase. Support fitting with a wrench, when loosening hex cap section.

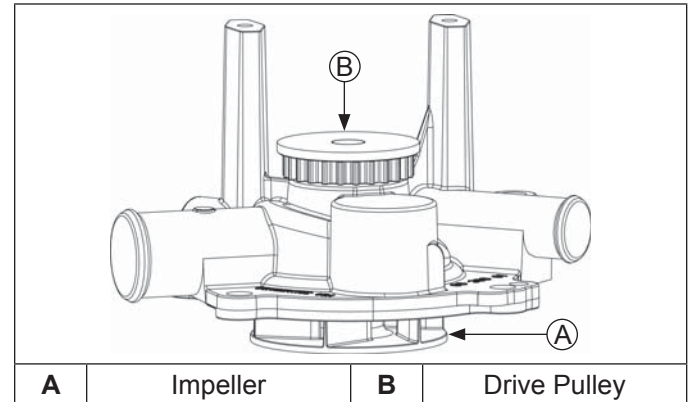
2. Remove screws securing water pump to crankcase.
3. Lift water pump up, and carefully work ferruled end of transfer tube out of fitting. Remove water pump with transfer tube and hose section attached. Remove and discard O-ring from within channel of pump housing.

4. Inspect and, if necessary, separate transfer tube and hose section from water pump. Remove hose clamps, noting their size differences and position of tangs.

IMPORTANT: 90° fitting in crankcase, which transfer tube is connected to, is sealed and installed at factory in a specific position. Do not loosen, remove, or alter mounted position of this fitting at any time. Contact factory service department for specific instructions if fitting is damaged, or its mounting is affected in any way.

Inspection and Service

Water Pump Details



Water/coolant pump consists of a sealed impeller assembly, which includes outer cover and a cogged drive pulley. When pump is mounted to crankcase, impeller fits into a cast recess, and cover seals against an O-ring outside perimeter of recess.

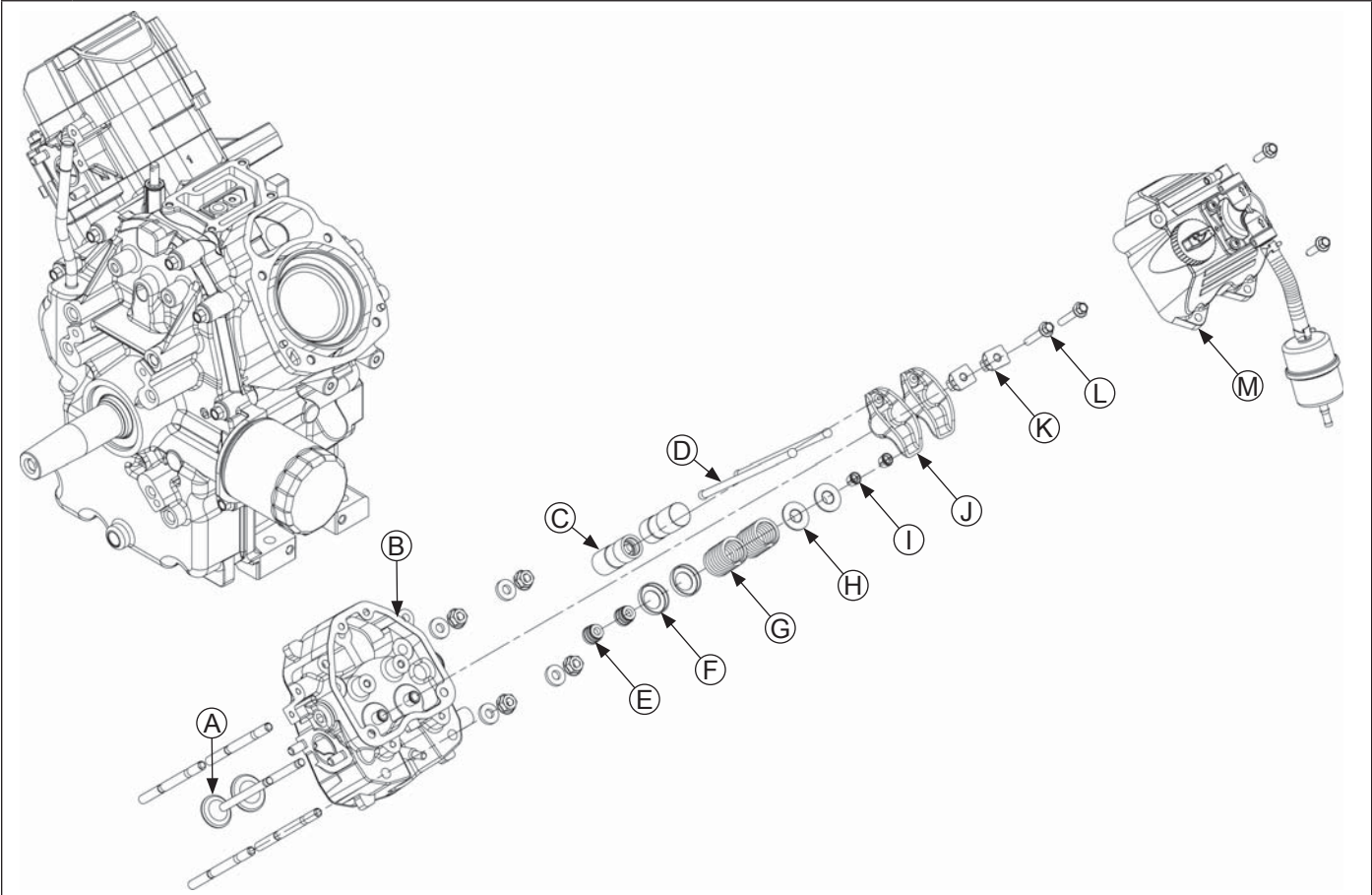
Impeller assembly is not serviceable, but it should be inspected for wear or damage.

1. Inspect impeller to make sure blades are in good condition and free of any cracks, nicks, or damage.
2. Impeller shaft should rotate smoothly, without binding or wobbling, and there should be no sign that coolant has leaked past shaft to outer surface of cover.
3. Check that drive pulley is not cracked or damaged in any way.

If your inspection causes you to doubt its reliability, water pump assembly should be replaced. Always use a new O-ring whenever water pump is removed. Do not reuse old O-ring or try to use RTV in its place.

Disassembly/Inspection and Service

Cylinder Head Components



A	Valve	B	Head	C	Hydraulic Lifter	D	Push Rods
E	Valve Stem Seal	F	Valve Spring Cap	G	Spring	H	Valve Spring Retainers
I	Valve Spring Keepers	J	Rocker Arms	K	Rocker Arm Pivot	L	Rocker Arm Screw
M	Valve Cover						

Remove Valve Covers

1. Remove screws from two lower valve cover mounting locations on each side.
2. Remove valve covers and valve cover gaskets. Note on which side oil fill or fuel pump is located, for correct reassembly later.

Remove Spark Plugs

1. Remove spark plugs from cylinder heads using a spark plug socket.

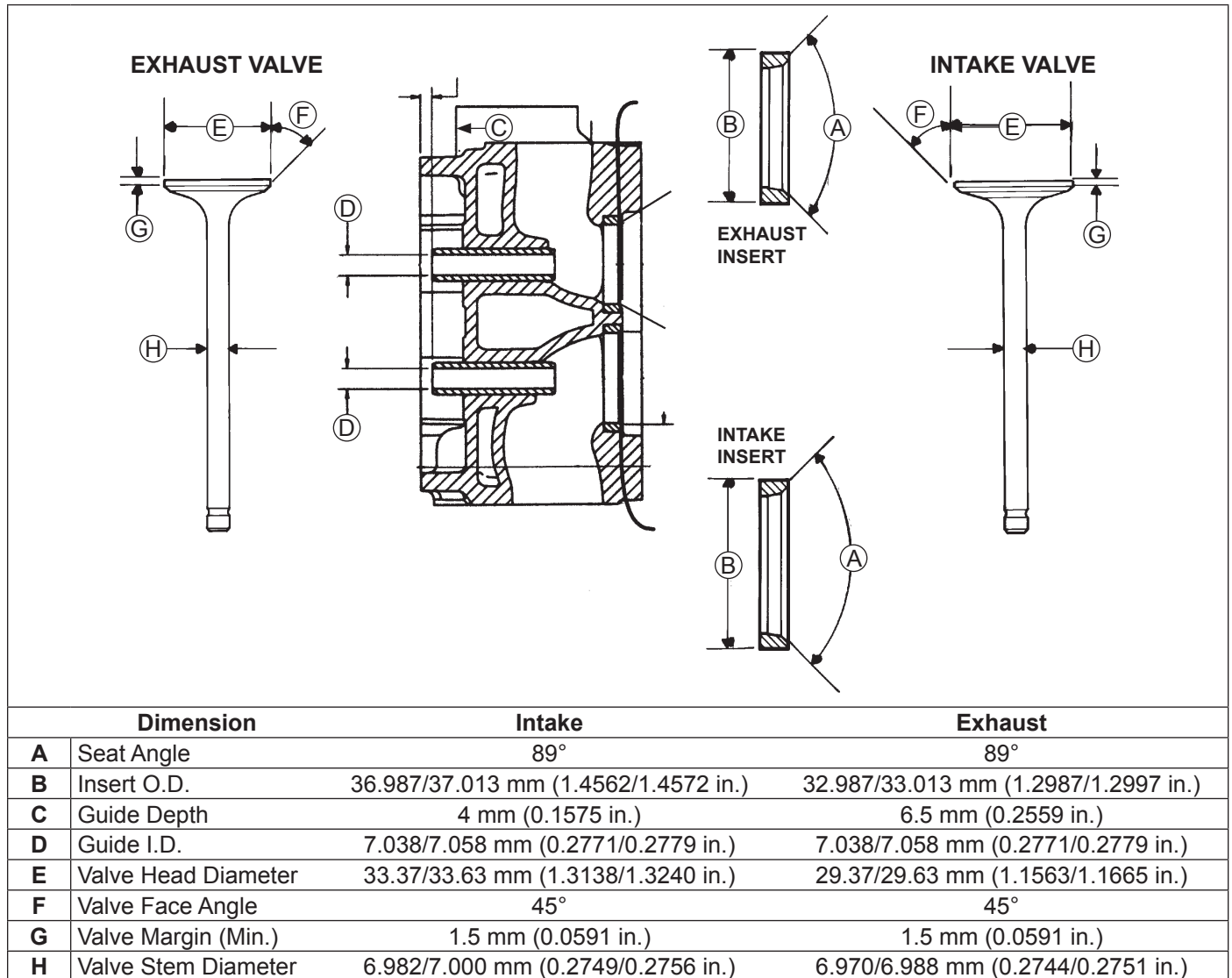
Remove Cylinder Heads and Valve Lifters

NOTE: It is not necessary to remove cylinder studs from crankcase unless replacement is intended. If studs are removed for any reason, discard old stud(s), do not reuse/reinstall. Use new studs and refer to assembly sequence for proper installation.

1. Rotate crankshaft of engine until valves of one cylinder are closed. Loosen rocker arm screws until rocker arms can be pivoted to free push rods.

2. Remove push rods and mark their location as either intake or exhaust, and cylinder 1 or 2. Push rods should always be reinstalled in their original position.
3. Repeat for opposite cylinder.
4. Remove nuts and washers from cylinder head studs. Carefully remove cylinder heads and head gaskets.
5. Remove hydraulic lifters using a hydraulic lifter removing tool (do not use a magnet). Mark them similar to push rods (intake or exhaust and cylinder 1 or 2). Hydraulic lifters should always be reinstalled in their original location.

Inspection and Service Valve Details



Disassemble Cylinder Heads

NOTE: These engines use a valve stem seal on intake and exhaust valves. Serial No. 3422000010 and lower used a seal on intake side only. Always use new seals when valves are removed from cylinder head. Replace seals if they are deteriorated or damaged in any way. Never reuse an old seal.

1. Remove screws, rocker arms and pivots from cylinder head(s).
2. Compress valve springs using a valve spring compressor and remove valve spring keepers. Remove compressor.
3. With keepers taken out following items can be removed.
 - valve spring retainers
 - valve springs
 - valve spring caps
 - intake and exhaust valves
 - valve stem seals (intake valve only)
4. Repeat above procedure for other cylinder head. Do not interchange parts from one cylinder head with parts from other cylinder head.

After cleaning, check flatness of cylinder head and corresponding top surface of crankcase, using a surface plate or piece of glass and feeler gauge. Maximum allowable out of flatness is 0.076 mm (0.003 in.).

Carefully inspect valve mechanism parts. Inspect valve springs and related hardware for excessive wear or distortion. Check valves and valve seat area or inserts for evidence of deep pitting, cracks, or distortion. Check clearance of valve stems in guides.

Disassembly/Inspection and Service

Hard starting or loss of power accompanied by high fuel consumption may be symptoms of faulty valves. Although these symptoms could also be attributed to worn rings, remove and check valves first. After removal, clean valve heads, faces, and stems with a power wire brush.

Then, carefully inspect each valve for defects such as a warped head, excessive corrosion, or a worn stem end. Replace valves found to be in bad condition.

Valve Guides

If a valve guide is worn beyond specifications, it will not guide valve in a straight line. This may result in burnt valve faces or seats, loss of compression, and excessive oil consumption.

To check valve guide-to-valve stem clearance, thoroughly clean valve guide and, using a split-ball gauge, measure inside diameter of guide. Then, using an outside micrometer, measure diameter of valve stem at several points on stem where it moves in valve guide. Use largest stem diameter to calculate clearance by subtracting stem diameter from guide diameter. If intake clearance exceeds 0.038/0.076 mm (0.0015/0.0030 in.) or exhaust clearance exceeds 0.050/0.088 mm (0.0020/0.0035 in.), determine whether valve stem or guide is responsible for excessive clearance.

Maximum (I.D.) wear on intake valve guide is 7.134 mm (0.2809 in.) while 7.159 mm (0.2819 in.) is maximum allowed on exhaust guide. Guides are not removable but can be reamed 0.25 mm (0.010 in.) oversize. Valves with 0.25 mm oversize stems must then be used.

If guides are within limits but valve stems are worn beyond limits, install new valves.

Valve Seat Inserts

Hardened steel alloy intake and exhaust valve seat inserts are press fitted into cylinder head. Inserts are not replaceable but can be reconditioned if not too badly pitted or distorted. If cracked or badly warped, cylinder head should be replaced.

Recondition valve seat inserts following instructions provided with valve seat cutter being used. Final cut should be made with an 89° cutter as specified for valve seat angle. Cutting proper 45° valve face angle as specified, and proper valve seat angle (44.5°, half of full 89° angle), will achieve desired 0.5° (1.0° full cut) interference angle where maximum pressure occurs on outside diameters of valve face and seat.

Lapping Valves

Reground or new valves must be lapped in, to provide proper fit. Use a hand valve grinder with a suction cup for final lapping. Lightly coat valve face with a fine grade of grinding compound, then rotate valve on its seat with grinder. Continue grinding until a smooth surface is obtained on seat and on valve face. Thoroughly clean cylinder head in soap and hot water to remove all traces of grinding compound. After drying cylinder head, apply a light coating of SAE 10 oil to prevent rusting.

Intake Valve Stem Seal

These engines use valve stem seals on intake valves. Always use a new seal when valves are removed from cylinder head. Seals should also be replaced if deteriorated or damaged in any way. Never reuse an old seal.

Hydraulic Lifters Inspection

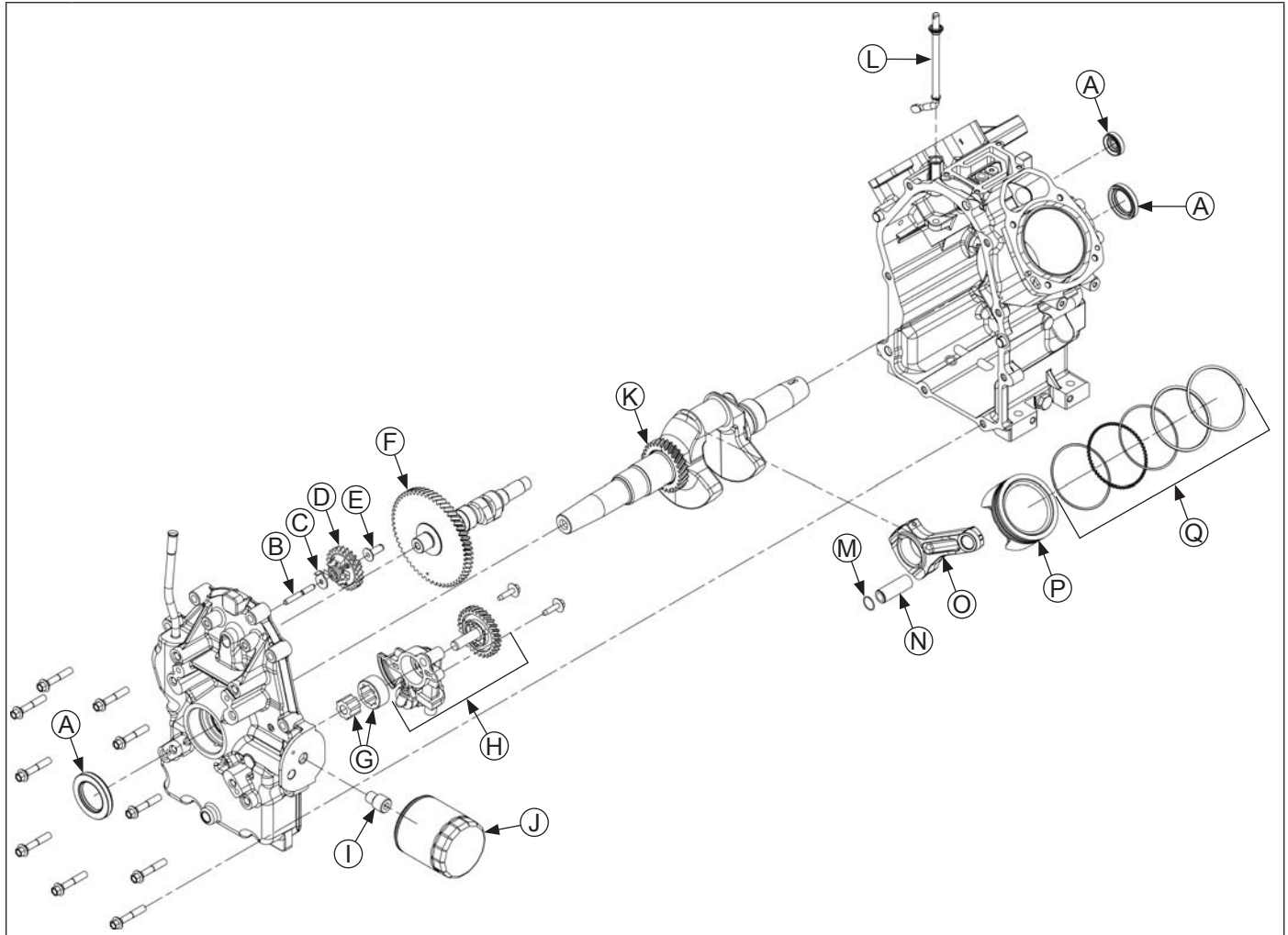
Check base surface of hydraulic lifters for wear or damage. If lifters need to be replaced, apply a liberal coating of Kohler lubricant to base of each new lifter before it is installed.

Bleeding Lifters

To prevent a possible bent push rod or broken rocker arm, it is important to bleed any excess oil out of lifters before they are installed.

1. Cut a 50-75 mm (2-3 in.) piece from end of an old push rod and chuck it in a drill press.
2. Lay a rag or shop towel on table of drill press and place lifter, open end up, on towel.
3. Lower chucked push rod until it contacts plunger in lifter. Slowly pump plunger two or three times to force oil out of feed hole in side of lifter.

Crankcase Components



A	Oil Seal	B	Governor Gear Shaft	C	Locking Tab Thrust Washer	D	Governor Gear
E	Regulating Pin	F	Cam	G	Gerotor	H	Oil Pump Assembly
I	Nipple	J	Oil Filter	K	Crankshaft	L	Governor Cross Shaft
M	Piston Pin Retainer	N	Piston Pin	O	Connecting Rod	P	Piston
Q	Piston Rings						

Remove Closure Plate

1. Remove screws securing closure plate to crankcase. If a thick washer is installed under screw head in #10 location, and/or one silver (ground) screw is used, (normally No. 4 or 6 position), note these special assembly details for proper reassembly later.
2. Locate three splitting tabs, which are cast into perimeter of closure plate. Insert drive end of a 1/2" breaker bar between top splitting tab and crankcase. Hold handle horizontal and pull it toward you to break RTV seal. If necessary, pry at bottom splitting tabs also. Do not pry on sealing surfaces, as this could cause leaks. Carefully pull closure plate from crankcase.

Inspection

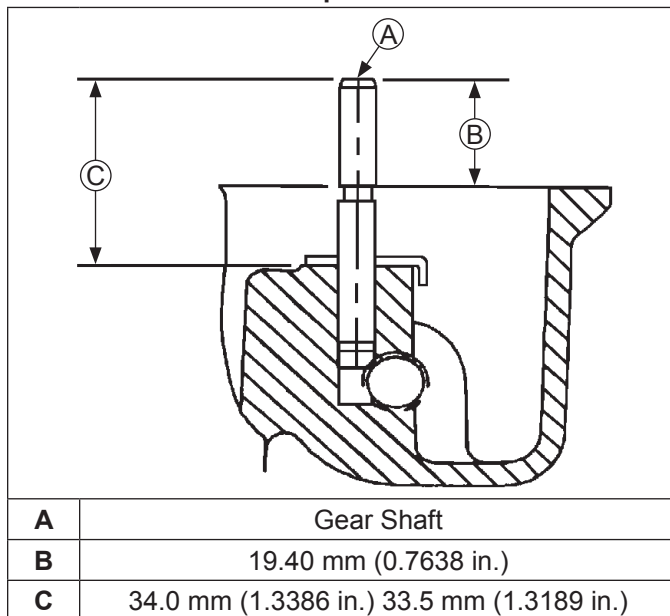
Inspect oil seal in closure plate and remove it if it is worn or damaged.

Inspect main bearing surface for wear or damage. Replace closure plate assembly if required.

Disassembly/Inspection and Service

Governor Gear Assembly

Governor Shaft Press Depth Details



Governor gear assembly is located inside closure plate. If service is required, refer to these procedures.

Inspection

Inspect governor gear teeth. Replace gear if it is worn, chipped, or if any teeth are missing. Inspect governor weights. They should move freely in governor gear.

Disassembly

NOTE: Governor gear is held onto shaft by small molded tabs in gear. When gear is removed from shaft, these tabs are destroyed and gear must be replaced. Therefore, remove gear only if absolutely necessary.

Governor gear must be replaced once it is removed from closure plate.

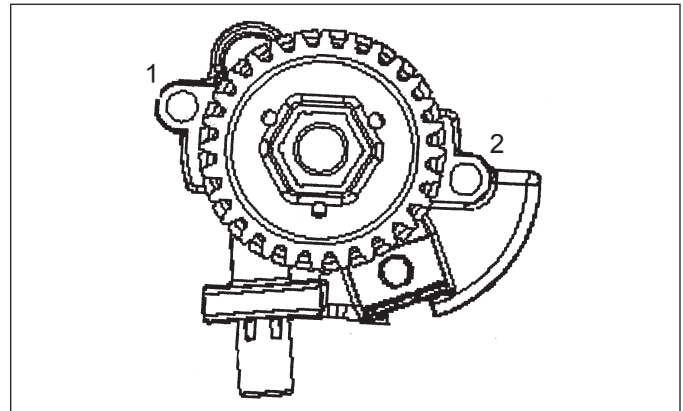
1. Remove regulating pin and governor gear assembly.
2. Remove locking tab thrust washer located under governor gear assembly.
3. Carefully inspect governor gear shaft and replace it only if it is damaged. After removing damaged shaft, press or lightly tap replacement shaft into closure plate to depth shown.

Reassembly

1. Install locking tab thrust washer on governor gear shaft with tab down.
2. Position regulating pin within governor gear/flyweight assembly and slide both onto governor shaft.

Oil Pump Assembly

Oil Pump Torque Sequence



Oil pump is mounted inside of closure plate. If service is required, refer to these following service procedures

Disassembly

1. Remove screws.
2. Remove oil pump assembly from closure plate.
3. Remove oil pump rotor.
4. Remove oil pickup by unhooking locking clip, and pulling it free from oil pump body.
5. Relief valve is a one-piece style, staked to oil pump housing removal should not be attempted, nor is internal servicing possible. If a problem with relief valve is encountered, oil pump should be replaced.

Inspection

Inspect oil pump housing, gear, and rotors for nicks, burrs, wear, or any visible damage. If any parts are worn or damaged, replace oil pump.

Inspect oil pressure relief valve piston. It should be free of nicks or burrs.

Check spring for wear or distortion. Free length of spring should be approximately 47.4 mm (1.8 in.). Replace spring if it is distorted or worn.

Reassembly

1. Install pressure relief valve piston and spring.
2. Install oil pickup to oil pump body. Lubricate O-ring with oil and make sure it remains in groove as pickup is being installed.
3. Install rotor.
4. Install oil pump body to closure plate and secure with screws. Torque screws as follows:
 - a. Install fastener into screw location 1 and lightly tighten to position pump.
 - b. Install fastener into screw location 2 and fully torque to recommended value.
 - c. Torque fastener in screw location 1 to 10.7 N·m (95 in. lb.) into new holes, or 6.7 N·m (60 in. lb.) into used holes.
5. After torquing, rotate gear and check for freedom of movement. Make sure there is no binding. If binding occurs, loosen screws, reposition pump, retorque screws and recheck movement.

Remove Camshaft

1. Remove camshaft and shims.

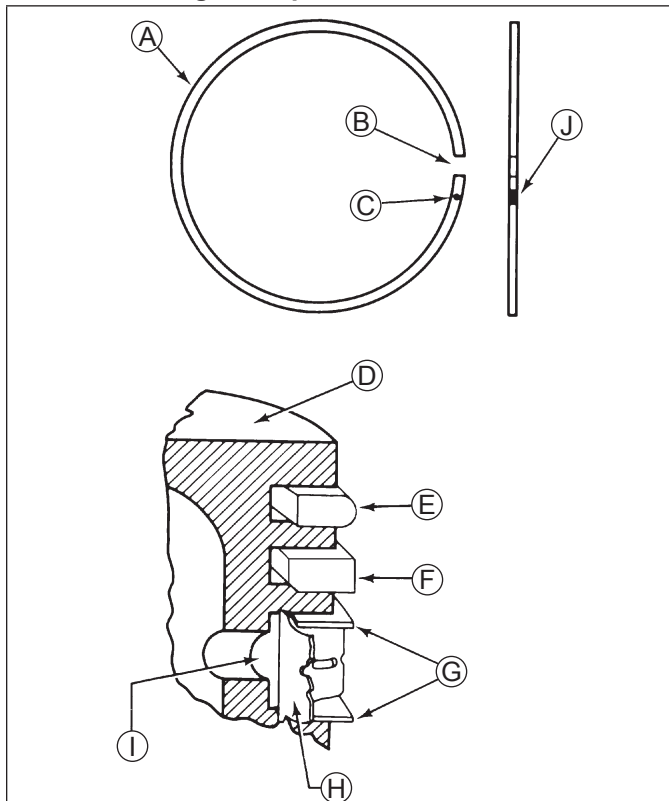
Remove Connecting Rods with Pistons and Rings

NOTE: If a carbon ridge is present at top of either cylinder bore, use a ridge reamer tool to remove it before attempting to remove piston.

NOTE: Cylinders are numbered on crankcase. Use numbers to mark each end cap and connecting rod/piston assembly for reassembly later. Do not mix end caps and connecting rods.

1. Remove screws securing closest connecting rod end cap. Remove end cap.
2. Carefully remove connecting rod and piston assembly from cylinder bore.
3. Repeat above procedure for other connecting rod and piston assembly.

Piston and Rings Components and Details



A	Piston Ring	B	End Gap
C	Identification Mark	D	Piston
E	Top Compression Ring	F	Center Compression Ring
G	Rails	H	Expander
I	Oil Control Ring (3 Piece)	J	Dye Colored Stripe

Inspection

Scuffing and scoring of pistons and cylinder walls occurs when internal engine temperatures approach welding point of piston. Temperatures high enough to do this are created by friction, which is usually attributed to improper

lubrication and/or overheating of engine.

Normally, very little wear takes place in piston boss-piston pin area. If original piston and connecting rod can be reused after new rings are installed, original pin can also be reused but new piston pin retainers are required. Piston pin is included as part of piston assembly – if pin boss in piston or pin are worn or damaged, a new piston assembly is required.

Ring failure is usually indicated by excessive oil consumption and blue exhaust smoke. When rings fail, oil is allowed to enter combustion chamber where it is burned along with fuel. High oil consumption can also occur when piston ring end gap is incorrect because ring cannot properly conform to cylinder wall under this condition. Oil control is also lost when ring gaps are not staggered during installation.

When cylinder temperatures get too high, lacquer and varnish collect on pistons causing rings to stick, which results in rapid wear. A worn ring usually takes on a shiny or bright appearance.

Scratches on rings and pistons are caused by abrasive material such as carbon, dirt, or pieces of hard metal.

Detonation damage occurs when a portion of fuel charge ignites spontaneously from heat and pressure shortly after ignition. This creates two flame fronts which meet and explode to create extreme hammering pressures on a specific area of piston. Detonation generally occurs from using low octane fuels.

Preignition or ignition of fuel charge before timed spark can cause damage similar to detonation. Preignition damage is often more severe than detonation damage. Preignition is caused by a hot spot in combustion chamber from sources such as glowing carbon deposits, blocked cooling fins, an improperly seated valve, or wrong spark plug(s).

Replacement pistons are available in STD bore size, and in 0.25 mm (0.010 in.), and 0.50 mm (0.020 in.) oversize. Replacement pistons include new piston ring sets and new piston pins.

Replacement ring sets are also available separately for STD, 0.25 mm (0.010 in.), and 0.50 mm (0.020 in.) oversize pistons. Always use new piston rings when installing pistons. Never use old rings.

Some important points to remember when servicing piston rings:

1. Cylinder bore must be deglazed before service ring sets are used.
2. If cylinder bore does not need reboring and if old piston is within wear limits and free of score or scuff marks, old piston may be reused.
3. Remove old rings and clean up grooves. Never reuse old rings.
4. Before installing new rings on piston, place top two rings, each in turn, in its running area in cylinder bore and check end gap. Compare ring gap to tolerances listed in Specifications.
5. After installing new compression (top and middle) rings on piston, check piston-to-ring side clearance. Compare clearance to tolerance listed in Specifications. If side clearance is greater than specified, a new piston must be used.

Disassembly/Inspection and Service

Install New Piston Rings

NOTE: Rings must be installed correctly. Ring installation instructions are usually included with new ring sets. Follow instructions carefully. Use a piston ring expander to install rings. Install bottom (oil control) ring first and top compression ring last.

To install new piston rings, proceed as follows:

- 1. Oil control ring (bottom groove): Install expander and then rails. Make sure ends of expander are not overlapped.
- 2. Middle compression ring (center groove): Install center ring using a piston ring installation tool. Make sure identification mark is up or dye colored stripe (if contained) is to left of end gap.
- 3. Top compression ring (top groove): Install top ring using a piston ring expender. Make sure identification mark is up or dye colored stripe (if contained), left of end gap.

Connecting Rods

Offset, stepped-cap connecting rods are used in all these engines.

Inspection and Service

Check bearing area (big end) for excessive wear, score marks, running and side clearances. Replace rod and cap if scored or excessively worn.

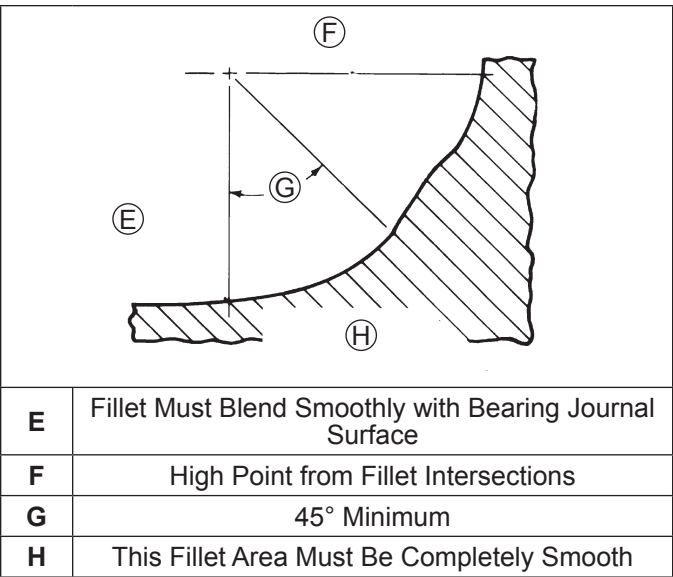
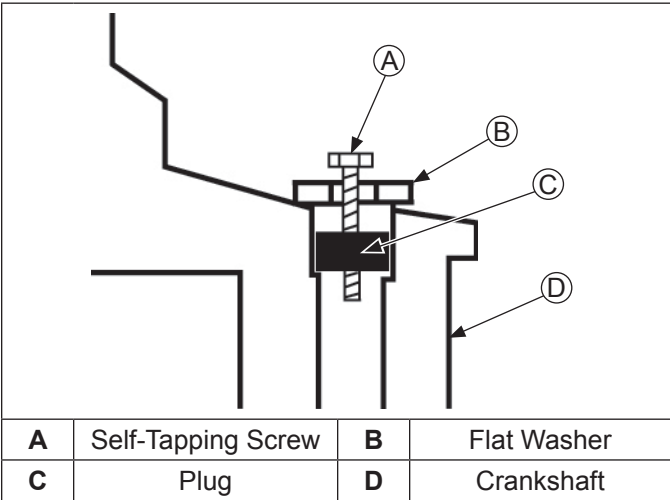
Service replacement connecting rods are available in STD crankpin size and 0.25 mm (0.010 in.) undersize. An 0.25 mm (0.010 in.) undersized rod can be identified by a drilled hole located in lower end of rod shank. Always refer to appropriate parts information to ensure correct replacements are used.

Remove Crankshaft

- 1. Carefully pull crankshaft from crankcase. Note thrust washer and shims if used.

Inspection and Service

Crankshaft Components and Details



Inspect gear teeth of crankshaft. If teeth are badly worn, chipped, or some are missing, replacement of crankshaft will be necessary.

Inspect crankshaft bearing surfaces for scoring, grooving, etc. Replaceable bearing is used in crankshaft bore of closure plate and/or crankcase. Do not replace bearing unless they show signs of damage or are out of running clearance 0.039/0.074 mm (0.0015/0.0029 in.). If crankshaft turns easily, without noise, and there is no evidence of scoring, grooving, etc., on races or bearing surfaces, bearing can be reused.

Inspect crankshaft keyways. If they are worn or chipped, replacement of crankshaft will be necessary. Inspect crankpin for score marks or metallic pickup. Slight score marks can be cleaned with crocus cloth soaked in oil. If wear limits, as stated in Clearance Specifications, are exceeded, it will be necessary to replace crankshaft or regrind crankpin to 0.25 mm (0.010 in.) undersize. If reground, a 0.25 mm (0.010 in.) undersize connecting rod (big end) must then be used to achieve proper running clearance. Measure crankpin for size, taper, and out-of-round.

Connecting rod journal can be ground 1 size under. When grinding a crankshaft, grinding stone deposits can get caught in oil passages, which could cause severe engine damage. Removing crankpin plug when crankshaft is ground provides easy access for removing any grinding deposits that may collect in oil passages. Use following procedure to remove and replace plug.

Remove Crankshaft Plug

- 1. Drill a 3/16 in. hole through plug in crankshaft.
- 2. Thread a 3/4 in. or 1 in. long self-tapping screw with a flat washer into drilled hole. Flat washer must be large enough to seat against shoulder of plug bore.
- 3. Tighten self-tapping screw until it draws plug out of crankshaft.

Install New Crankshaft Plug

Use 1 single cylinder camshaft pin, as a driver and tap plug into plug bore until it seats at bottom of bore. Make sure plug is tapped in evenly to prevent leakage.

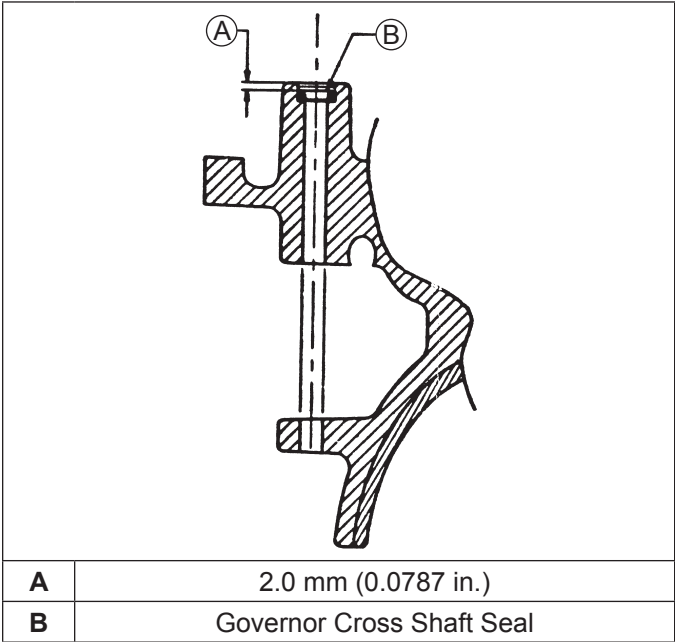
Remove Governor Cross Shaft

NOTE: Always use a new retaining ring when reassembling. Do not reuse old retaining ring.

1. Remove retaining ring and nylon washer from governor cross shaft.
2. Remove cross shaft and small washer out through inside of crankcase.

Governor Cross Shaft Oil Seal

Cross Shaft Oil Seal Details



Remove governor cross shaft oil seal from crankcase and replace it with a new one if seal is damaged and/or leaks. Install new seal to depth shown using a seal installer.

Remove Flywheel End Oil Seals

1. Remove flywheel end crankshaft and camshaft oil seals from crankcase.

Crankcase

These engines contain a cast-iron cylinder liner that may be reconditioned as follows:

Inspection and Service

NOTE: If bore is beyond wear limit, a new miniblock or short block will be required.

Check all gasket surfaces to make sure they are free of gasket fragments. Gasket surfaces must also be free of deep scratches or nicks.

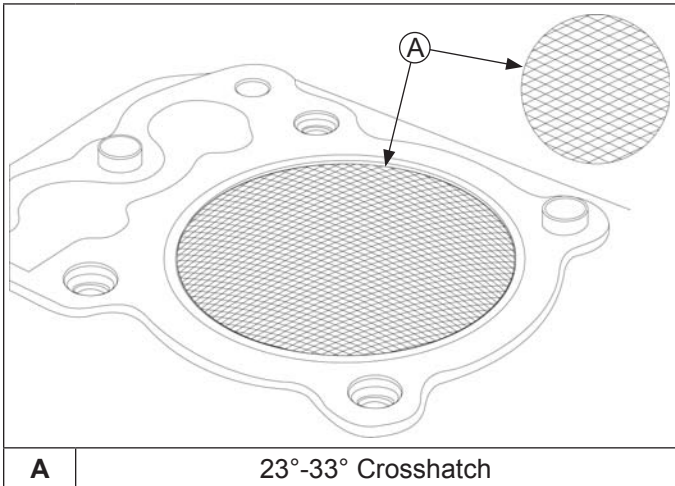
Inspect main bearing (if equipped) for wear or damage. Replace crankcase using a mini-block or short block if required.

Check cylinder bore for scoring. In severe cases, unburned fuel can cause scuffing and scoring of cylinder wall. It washes necessary lubricating oils off piston and cylinder wall. As raw fuel seeps down cylinder wall, piston rings make metal to metal contact with wall. Scoring of cylinder wall can also be caused by localized hot spots resulting from a cooling system problem or from inadequate or contaminated lubrication.

If cylinder bore is badly scored, excessively worn, tapered, or out-of-round, resizing is necessary. Use an inside micrometer to determine amount of wear, then select nearest suitable oversize of either 0.08 mm (0.003 in.), 0.25 mm (0.010 in.), or 0.50 mm (0.020 in.). Resizing to one of these oversizes will allow usage of available oversize piston and ring assemblies. Initially, resize using a boring bar, then use following procedures for honing cylinder.

Honing

Detail



While most commercially available cylinder hones can be used with either portable drills or drill presses, use of a low speed drill press is preferred as it facilitates more accurate alignment of bore in relation to crankshaft crossbore. Honing is best accomplished at a drill speed of about 250 RPM and 60 strokes per minute. After installing coarse stones in hone, proceed as follows:

1. Lower hone into bore and after centering, adjust so that stones are in contact with cylinder wall. Use of a commercial cutting-cooling agent is recommended.
2. With lower edge of each stone positioned even with lowest edge of bore, start drill and honing process. Move hone up and down while resizing to prevent formation of cutting ridges. Check size frequently.
3. When bore is within 0.064 mm (0.0025 in.) of desired size, remove coarse stones and replace with burnishing stones. Continue with burnishing stones until within 0.013 mm

(0.0005 in.) of desired size and then use finish stones (220-280 grit) and polish to final size. A crosshatch should be observed if honing is done correctly. Crosshatch should intersect at approximately 23-33° off horizontal. Too flat an angle could cause rings to skip and wear excessively, too steep an angle will result in high oil consumption.

Disassembly/Inspection and Service

4. After resizing, check bore for roundness, taper, and size. Use an inside micrometer, telescoping gauge, or bore gauge to take measurements. Measurements should be taken at three locations in cylinder—at top, middle, and bottom. Two measurements should be taken (perpendicular to each other) at each three locations.

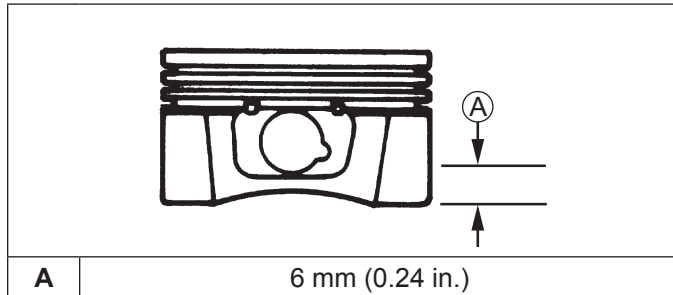
Clean Cylinder Bore After Honing

Proper cleaning of cylinder walls following boring and/or honing is very critical to a successful overhaul. Machining grit left in cylinder bore can destroy an engine in less than one hour of operation after a rebuild.

Final cleaning operation should always be a thorough scrubbing with a brush and hot, soapy water. Use a strong detergent that is capable of breaking down machining oil while maintaining a good level of suds. If suds break down during cleaning, discard dirty water and start again with more hot water and detergent. Following scrubbing, rinse cylinder with very hot, clear water, dry it completely, and apply a light coating of engine oil to prevent rusting.

Measuring Piston-to-Bore Clearance

Piston Detail



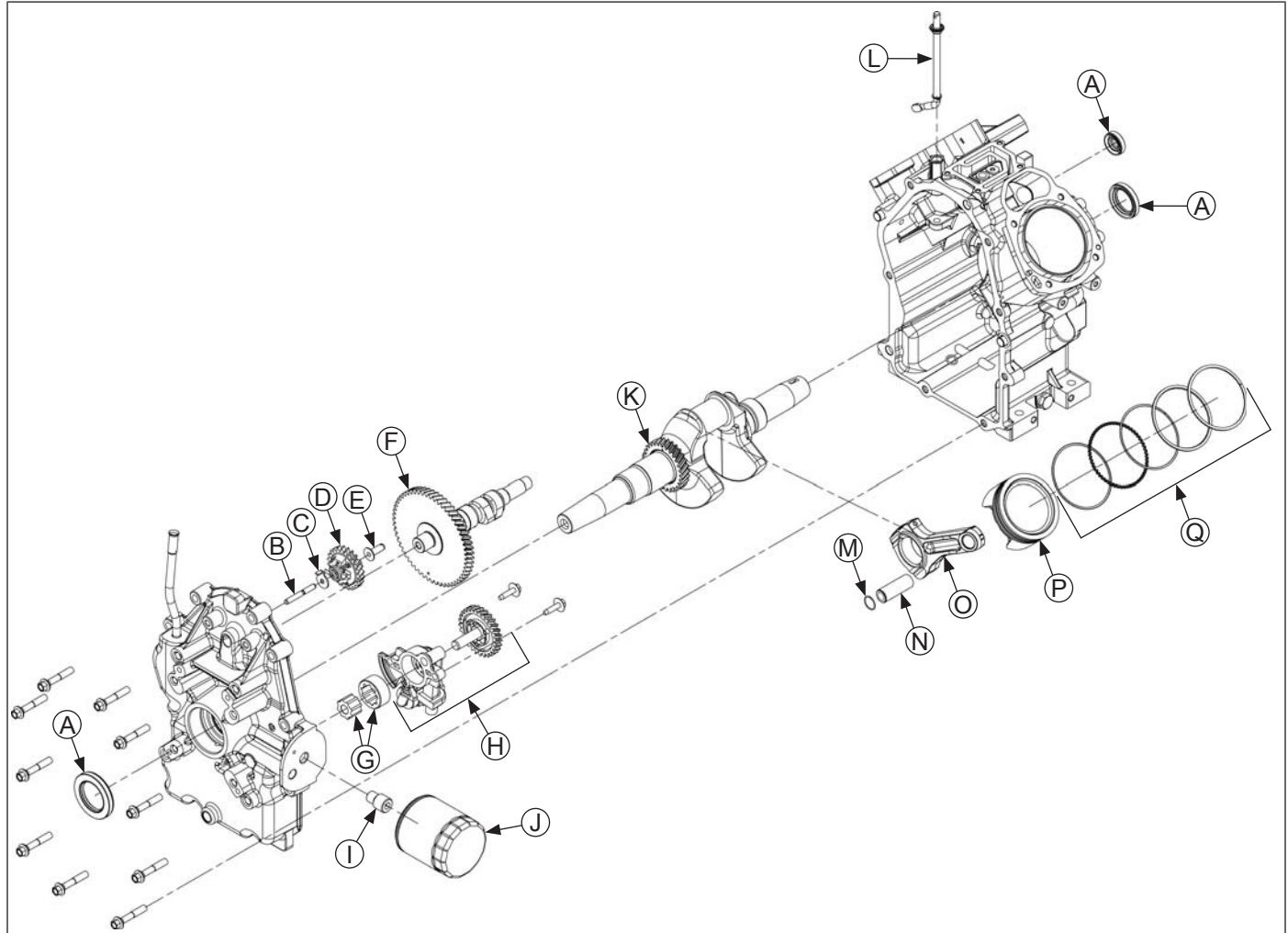
NOTE: Do not use a feeler gauge to measure piston-to-bore clearance—it will yield inaccurate measurements. Always use a micrometer.

Before installing piston into cylinder bore, it is necessary that clearance be accurately checked. This step is often overlooked, and if clearances are not within specifications, engine failure will usually result.

Use following procedure to accurately measure piston-to-bore clearance:

1. Use a micrometer and measure diameter of piston 6 mm (0.24 in.) above bottom of piston skirt and perpendicular to piston pin.
2. Use an inside micrometer, telescoping gauge, or bore gauge and measure cylinder bore. Take measurement approximately 63.5 mm (2.5 in.) below top of bore and perpendicular to piston pin.
3. Piston-to-bore clearance is difference between bore diameter and piston diameter (step 2 minus step 1).

Crankcase Components



A	Oil Seal	B	Governor Gear Shaft	C	Locking Tab Thrust Washer	D	Governor Gear
E	Regulating Pin	F	Camshaft	G	Gerotor	H	Oil Pump Assembly
I	Nipple	J	Oil Filter	K	Crankshaft	L	Governor Cross Shaft
M	Piston Pin Retainer	N	Piston Pin	O	Connecting Rod	P	Piston
Q	Piston Rings						

NOTE: Make sure engine is assembled using all specified torque values, tightening sequences and clearances. Failure to observe specifications could cause severe engine wear or damage. Always use new gaskets. Apply a small amount of oil to threads of critical fasteners before assembly, unless a Sealant or Loctite® is specified or preapplied.

Make sure all traces of any cleaner are removed before engine is assembled and placed into operation. Even small amounts of these cleaners can quickly break down lubricating properties of engine oil.

Check closure plate, crankcase, cylinder heads, and valve covers to be certain that all old sealing material has been removed. Use gasket remover, lacquer thinner, or paint remover to remove any remaining traces. Clean surfaces with isopropyl alcohol, acetone, lacquer thinner, or electrical contact cleaner.

Install Flywheel End Oil Seal and Camshaft Oil Seal

1. Check to make sure that there are no nicks or burrs in crankshaft and camshaft seal bores of crankcase.
2. Apply a light coat of engine oil to outside diameter of flywheel end oil seal.
3. Install oil seal into crankcase using a seal driver. Make sure oil seal is installed straight and true in bore, until tool bottoms against crankcase.
4. Apply a light coat of engine oil to outside diameter of camshaft oil seal.
5. Install camshaft oil seal to a depth of 1.0-1.5 mm (0.039-0.059 in.) below top of seal bore. Do not bottom seal in bore or oil passage may be obstructed.

Reassembly

Install Governor Cross Shaft

1. Lubricate governor cross shaft bearing surfaces in crankcase with engine oil. Apply a small amount of grease to lips of oil seal.
2. Slide small lower washer onto governor cross shaft and install cross shaft from inside of crankcase.
3. Install nylon washer onto governor cross shaft, then start push-on retaining ring. Hold governor shaft up in position, then place a 0.25 mm (0.010 in.) feeler gauge on top of nylon washer, and push retaining ring down shaft to secure. Remove feeler gauge, which will have established proper end play.
4. Pivot governor cross shaft so bottom end faces cylinder 1 side.

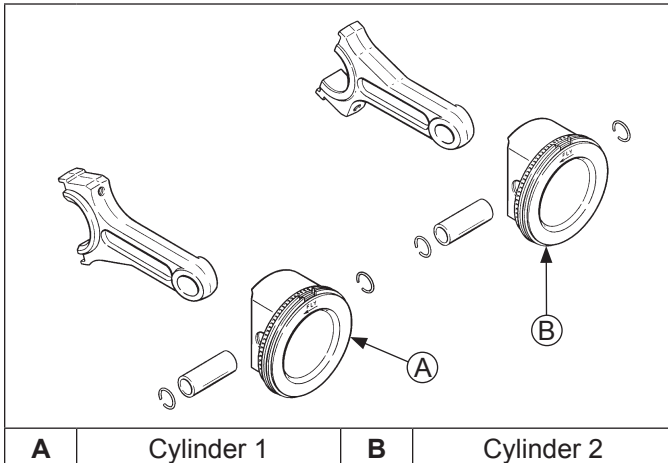
Install Crankshaft

NOTE: Apply cellophane tape over crankshaft keyway to prevent cutting oil seal during installation.

1. Lightly lubricate lips of crankshaft seal with grease.
2. Carefully slide flywheel end of crankshaft into crankcase through oil seal.

Install Connecting Rods with Pistons and Rings

Piston/Connecting Rod Details



NOTE: Cylinders are numbered on crankcase. Make sure to install piston, connecting rod and end cap into its appropriate cylinder bore, as previously marked at time of disassembly. Do not mix end caps and connecting rods.

NOTE: Proper orientation of piston/connecting rod assemblies inside engine is extremely important. Improper orientation can cause extensive wear or damage.

NOTE: Make sure to align chamfer of connecting rod with chamfer of its mating end cap. When installed, flat faces of connecting rods should face each other. Faces with raised rib should be toward outside.

1. Stagger piston rings in grooves until end gaps are 120° apart. Oil ring rails should also be staggered.
2. Lubricate cylinder bore, piston, and piston rings with engine oil. Compress rings of cylinder 1 piston using a piston ring compressor.

3. Lubricate crankshaft journals and connecting rod bearing surfaces with engine oil.
4. Make sure FLY stamping on pistons is facing towards flywheel side of engine. Use a hammer with rubber grip and gently tap piston down into cylinder. Be careful that oil ring rails do not spring free, between bottom of ring compressor and top of cylinder.
5. Guide lower end of connecting rod and rotate crankshaft to join two. Install rod cap to connecting rod using screws and torque in increments to 11.3 N·m (100 in. lb.).
6. Repeat above procedure for other connecting rod and piston assembly.

Install Camshaft

1. Inspect edges of camshaft keyway, make sure they are not nicked or burred. Use a seal protector (11/16") to prevent damaging seal lips, or dislodging inner spring when camshaft is installed. Cellophane tape over keyway is also recommended.
2. Lubricate camshaft bearing surfaces of crankcase and camshaft with engine oil. Apply a small amount of grease to lips of oil seal.
3. Rotate crankshaft and position timing mark of crankshaft gear at 12 o'clock position.
4. Turn governor cross shaft clockwise until lower end of shaft contacts crankcase (cylinder 1 side). Make sure cross shaft remains in this position while installing camshaft.
5. Slide camshaft into bearing surface of crankcase, positioning timing mark of camshaft gear at 6 o'clock position. Make sure that camshaft gear and crankshaft gear mesh, and timing marks are aligned.

Checking/Setting Camshaft End Play

1. Install shim removed during disassembly onto camshaft.
2. Position end play tool on camshaft.
3. Apply pressure on end play checking tool (pushing camshaft toward crankshaft). Use a feeler gauge to measure end play between shim and end play tool. Camshaft end play should be 0.076/0.127 mm (0.003/0.005 in.).
4. If camshaft end play is not within specified range, remove original shim and reinstall end play tool. Use a feeler gauge to determine clearance between camshaft and tool. Subtract 0.100 mm (0.004 in) from measured clearance to obtain required shim thickness. Refer to table below and install shim that matches calculated thickness. Repeat steps 1-3 to verify that correct end play exists.

Camshaft Shims

White:	0.69215/0.73025 mm (0.02725/0.02875 in.)
Blue:	0.74295/0.78105 mm (0.02925/0.03075 in.)
Red:	0.79375/0.83185 mm (0.03125/0.03275 in.)
Yellow:	0.84455/0.88265 mm (0.03325/0.03475 in.)
Green:	0.89535/0.99345 mm (0.03525/0.03675 in.)
Gray:	0.94615/0.98425 mm (0.03725/0.03875 in.)
Black:	0.99695/1.03505 mm (0.03925/0.04075 in.)

Oil Pump Assembly

Oil pump is mounted to inside of closure plate. If service was required, and oil pump was removed, refer to assembly procedures under Oil Pump Assembly in Reassembly.

Governor Assembly

Governor assembly is located inside closure plate. If service was required, and governor was removed, refer to assembly procedures under Governor Assembly in Reassembly.

Thrust Bearing, Washer and Shim

Some specifications use a thrust bearing, thrust washer, and shim to control end play of crankshaft. If these items were noted during disassembly, make sure they were reinstalled in proper sequence, as illustrated. A different procedure must be followed to check and adjust crankshaft end play on these models.

Race for thrust bearing presses loosely into closure plate. If it is not already installed, push it into crankshaft bore inside closure plate. Pack thrust bearing with heavy grease and stick bearing into race. Wipe some grease on face of thrust washer and stick it onto thrust bearing. Wipe some grease on face of original shim and stick it onto thrust washer.

Install closure plate onto crankcase without applying RTV sealant and secure it with only two or three fasteners at this time. Use a dial indicator to check crankshaft end play. End play should be 0.070/0.590 mm (0.0027/0.0232 in.). Shims are available in five color-coded thicknesses listed below if adjustment is needed.

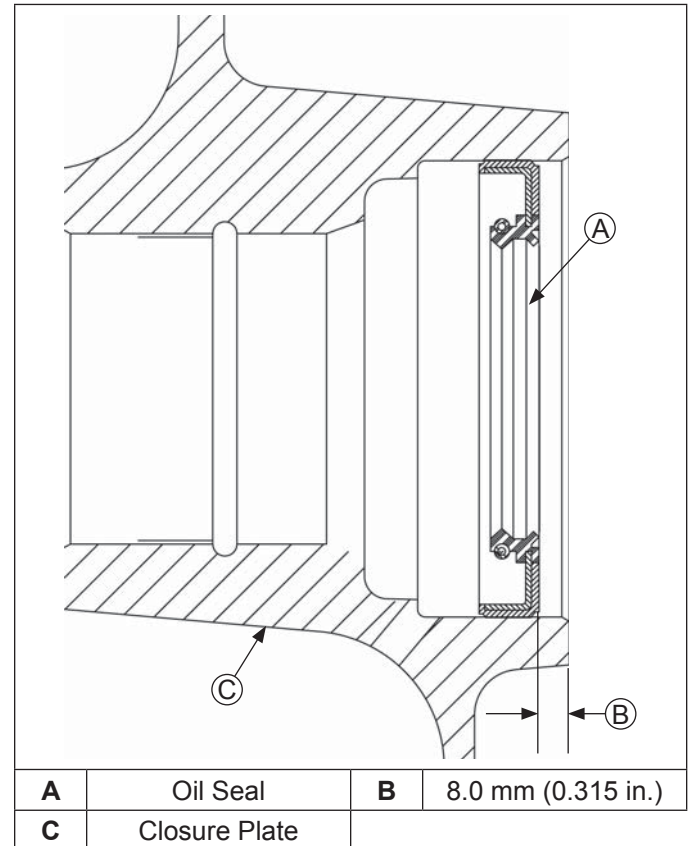
Crankshaft End Play Shims

Remove closure plate. If end play requires adjustment, remove original shim and install appropriate size replacement.

BLUE	0.48-0.52 mm (0.050 mm Nominal) (0.019 in.)
BLACK	0.667-0.705 mm (0.686 mm Nominal) (0.27 in.)
GREEN	0.8366-0.9127 mm (0.8750 mm Nominal) (0.34 in.)
YELLOW	1.9652-1.1414 mm (1.1033 mm Nominal) (0.043 in.)
RED	1.2938-1.3700 mm (1.3319 mm Nominal) (0.052 in.)

Install Closure Plate Oil Seal

Cylinder Head Torque Sequence

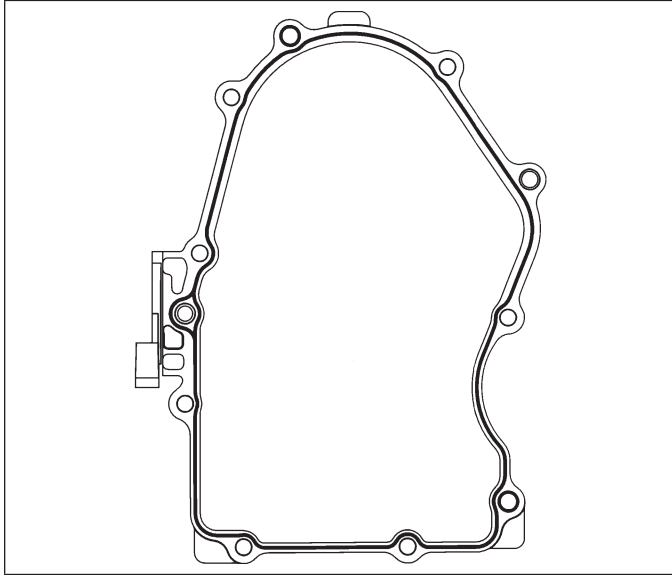


1. Check to make sure that there are no nicks or burrs in crankshaft bore of closure plate.
2. Apply a light coat of engine oil to outside diameter of oil seal.
3. Drive oil seal into closure plate using a seal driver. Make sure oil seal is installed straight and true in bore to depth shown.

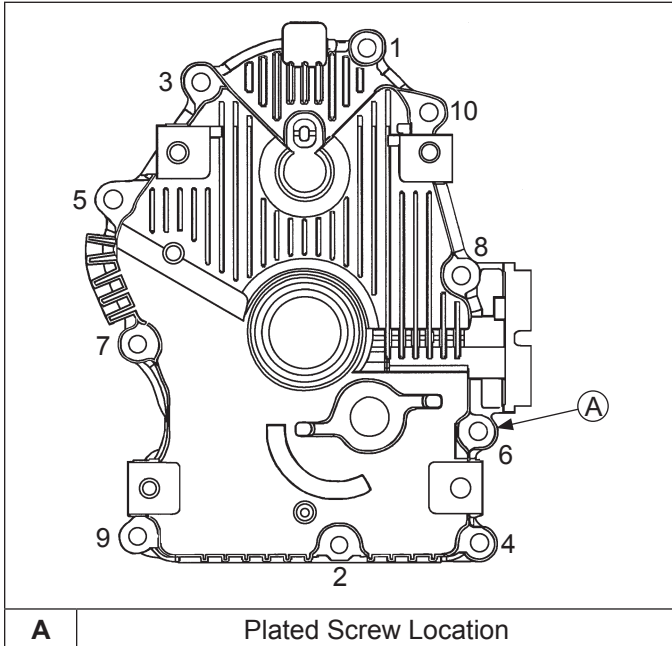
Reassembly

Install Closure Plate Assembly

Closure Plate Sealant Pattern



Torque Sequence



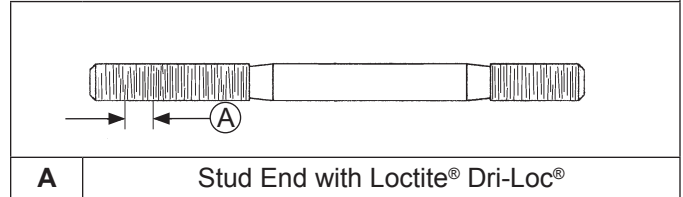
RTV silicone sealant is used as a gasket between closure plate and crankcase. Always use fresh sealant. Using outdated sealant can result in leakage.

1. Be sure sealing surfaces have been cleaned and prepared.
2. Check to make sure that there are no nicks or burrs on sealing surfaces of closure plate or crankcase.
3. Apply a 1/16" bead of sealant to sealing surface of closure plate.
4. Make sure end of governor cross shaft is lying against bottom of cylinder 1 inside of crankcase.
5. If alignment pins were removed previously, install them in their respective locations in crankcase.

6. Install closure plate on crankcase. Carefully seat camshaft and crankshaft into their mating bearings. Rotate crankshaft to help engage oil pump and governor gear meshes.
7. Install screws securing closure plate to crankcase. If a thick flat washer was used on one of screws, install it in number 10 location. Install silver plated (ground) screw in its original location (normally number 4 or 6 location). Torque fasteners, in torque sequence shown to 24.4 N·m (216 in. lb.).

Install Cylinder Studs

Piston/Connecting Rod Details

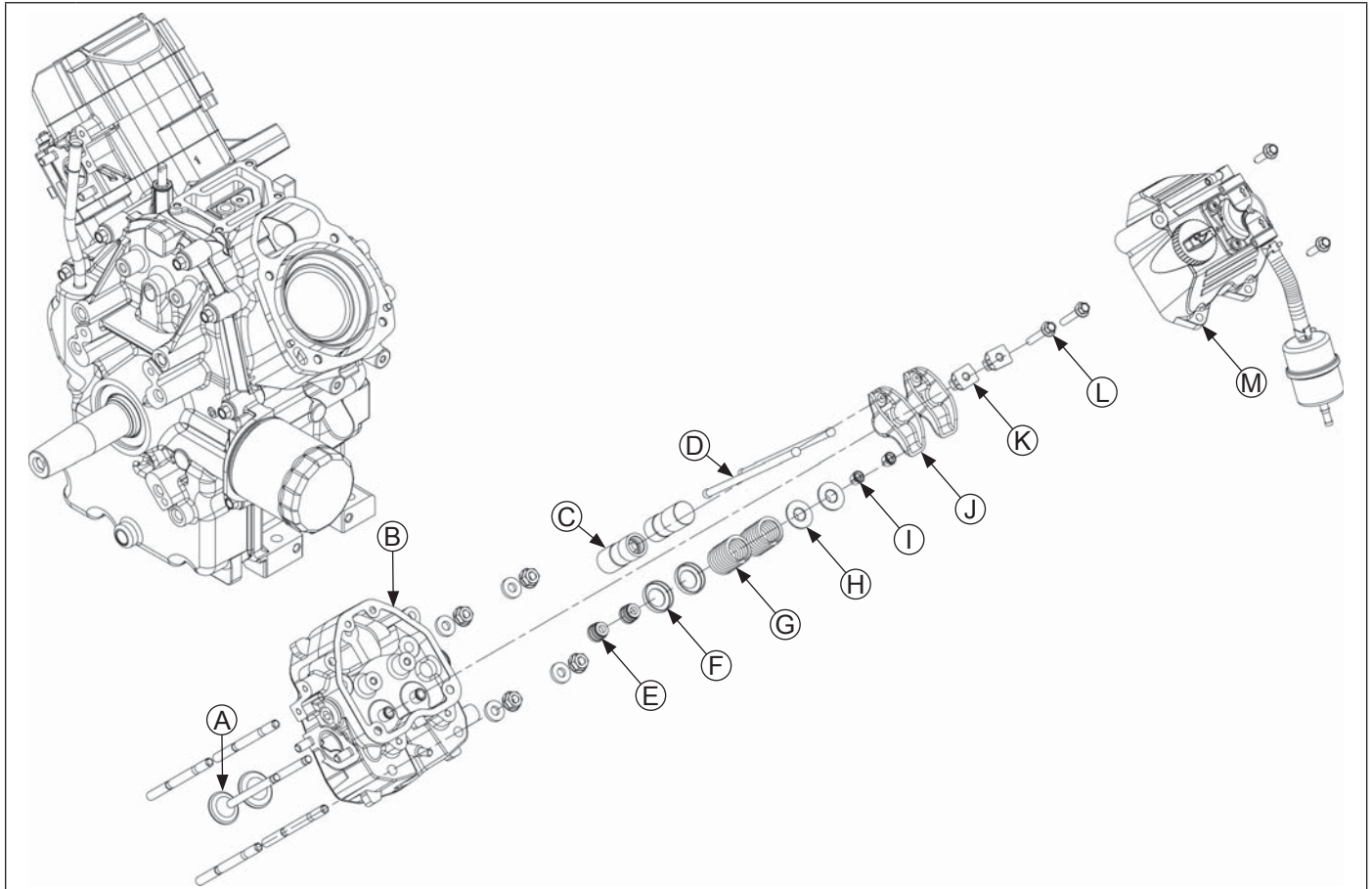


NOTE: Do not reinstall or attempt to reuse any cylinder studs that have been removed. Discard any removed stud(s) and replace with new.

If any of cylinder studs were removed, install new stud(s) as follows:

1. Identify longer threaded end of new stud containing Loctite® Dri-Loc®.
2. Tighten nuts together on shorter threaded section, with identification mark on end.
3. Thread end of stud with Loctite® into crankcase, until an exposed stud height of 75 mm (2 61/64 in.) is obtained. End with dash mark must be out. When threading in studs, use a steady tightening motion, without interruption, until proper height is obtained. Frictional heat from engaging threads may otherwise cause locking compound to set up prematurely. Remove two nuts.
4. Repeat steps 1-3 for each of studs.

Cylinder Head Components



A	Valve	B	Head	C	Hydraulic Lifter	D	Push Rods
E	Valve Stem Seal	F	Valve Spring Cap	G	Spring	H	Valve Spring Retainers
I	Valve Spring Keepers	J	Rocker Arms	K	Rocker Arm Pivot	L	Rocker Arm Screw
M	Valve Cover	N	Fuel Pump				

Install Hydraulic Lifters

NOTE: Hydraulic lifters should always be installed in same position as before disassembly.

1. Lubricate lifters and lifter bores in crankcase with engine oil.
2. Install lifters into their respective lifter bores according to location and cylinder number marked during assembly.

Valve Stem Seals

These engines use valve stem seals on intake and exhaust valves. Always use a new seal before valves are installed in cylinder head. Also, replace seals if they are deteriorated or damaged in any way. Never reuse an old seal.

Assemble Cylinder Heads

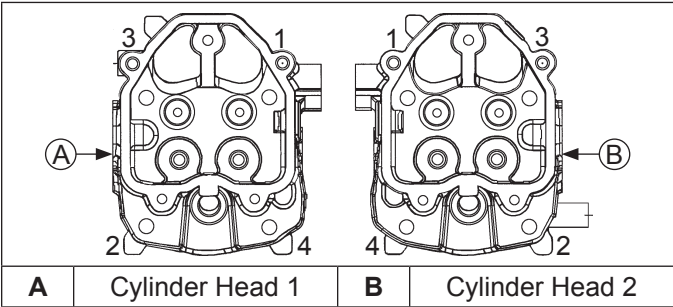
Prior to installation, lubricate all components with engine oil, paying particular attention to lip of valve stem seal, valve stems and valve guides. Install following items in order listed below using a valve spring compressor.

- Valve stem seals
- Intake and exhaust valves
- Valve spring caps
- Valve springs
- Valve spring retainers
- Valve spring keepers

Reassembly

Install Cylinder Heads

Cylinder Head Torque Sequence



NOTE: Match numbers embossed on cylinder heads and crankcase.

1. Check to make sure there are no nicks or burrs on sealing surfaces of cylinder head or crankcase.
2. Rotate crankshaft to position piston in cylinder 1 to top dead center (TDC) on compression stroke.
3. Install a new cylinder head gasket.
4. Install cylinder 1 head onto number 1 side mounting studs.
5. Install a plain washer onto each stud and secure with a nut.
6. Torque nuts in two steps, first to 16.9 N·m (150 in. lb.) and then to 33.9 N·m (300 in. lb.), using torque sequence shown.
7. Repeat installation procedure for cylinder 2 side head.

Install Push Rods and Rocker Arms

NOTE: Push rods must always be installed in same position as before disassembly.

1. Note mark or tag identifying push rod as either intake or exhaust for cylinder 1. Lightly apply engine oil or grease to ends of push rods and install. Make sure that each push rod ball seats in its respective hydraulic lifter socket.
2. Apply grease to contacting surfaces of rocker arms and rocker arm pivots. Install rocker arms and rocker arm pivots on cylinder head.
3. Install new rocker arm screws with Dri-Loc® thread locking compound on threads. Torque screws to 11.3 N·m (100 in. lb.). When tightening, use a steady motion, without interruption, until proper torque is achieved. Frictional heat from engaging threads may otherwise cause locking compound to set prematurely. If new screws are not available, apply Loctite® 242® to bottom 4 or 5 threads. Then install and torque screws to 11.3 N·m (100 in. lb.).
4. Use a spanner wrench or rocker arm lifting tool (see Tools and Aids) to lift rocker arms and position push rods underneath.
5. Rotate crankshaft so piston in cylinder 2 is at top dead center on compression stroke, and repeat steps for remaining cylinder. Do not interchange parts from one cylinder head with parts from other cylinder head.

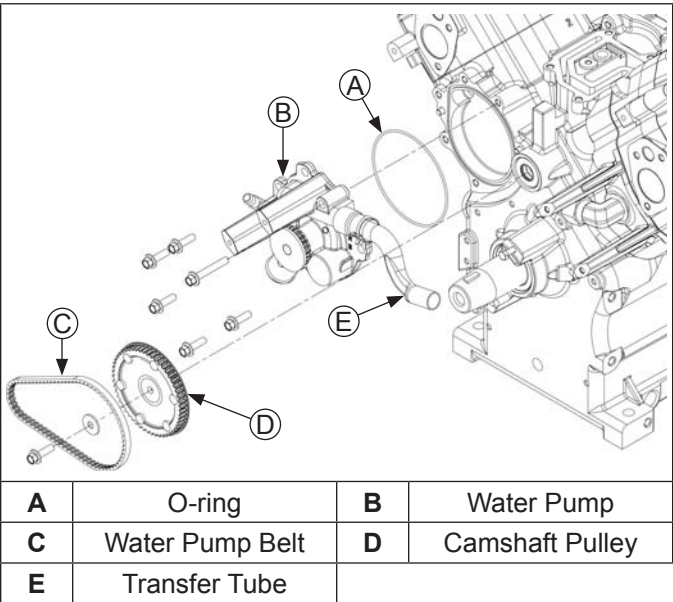
6. Rotate crankshaft to check for free operation of valve train. Check clearance between valve spring coils at full lift. Minimum allowable clearance is 0.25 mm (0.010 in).

Install Valve Covers

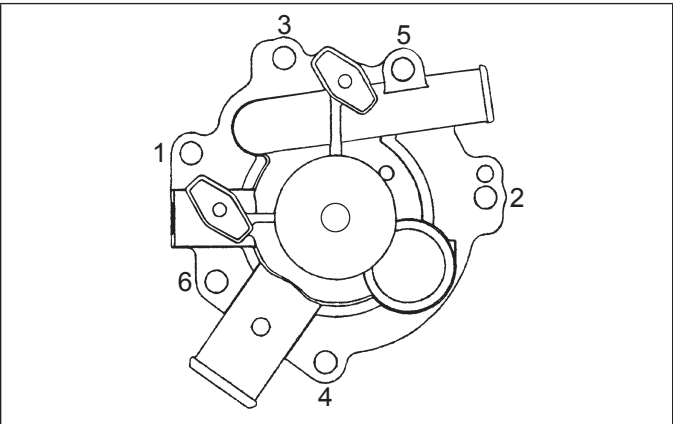
1. Make sure sealing surfaces of cylinder heads and valve covers are clean and free of all old gasket material.
2. Install new valve cover gaskets onto valve covers.
3. Install valve covers with gaskets in their original locations.
4. Install lower mounting screws in each cover, and finger tighten only. Upper screws will be installed later.

Install Water Pump, Drive Belt, and Transfer Tube Assembly

Water Pump Components



Water Pump Torque Sequence



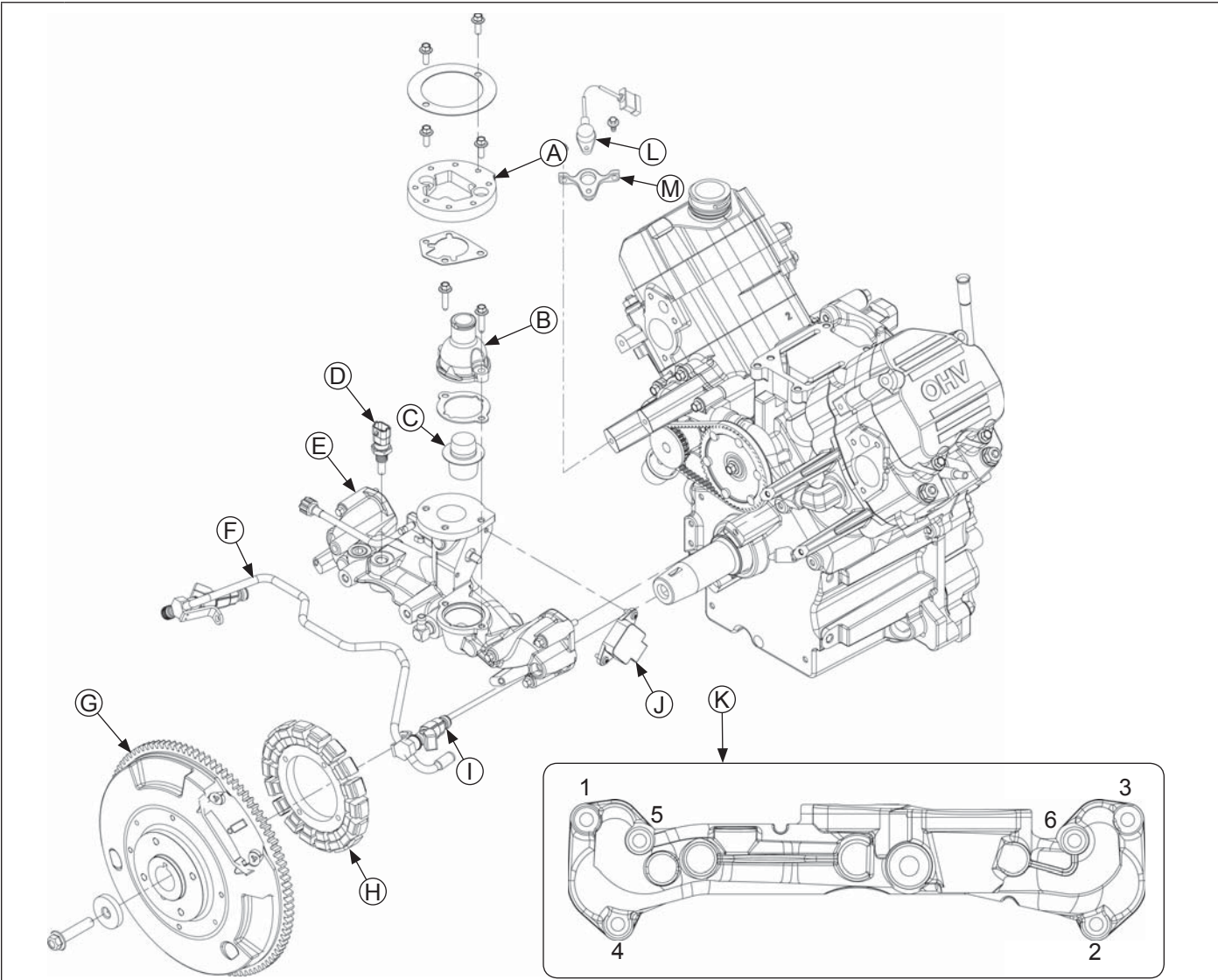
NOTE: A mark or dot of paint applied to top, of pulley, indicating keyway location, will make installation easier.

NOTE: When installation is complete, tangs of two hose clamps should face outward, away from flywheel and slightly down.

1. Remove seal protector and/or protective tape (if used) from over keyway and make sure end of camshaft is clean and free of any nicks or damage. Install and fully seat key, squarely into keyway. Be careful not to contact camshaft seal. Test fit cam pulley onto shaft and key; it must slide on without force or restriction. Remove pulley.
 2. If water pump by-pass hose fitting was removed previously, apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) on threads and tighten it into pump. Orient fitting so outlet points in 11 o'clock position.
 3. Check sealing surfaces of water pump and crankcase. They must be clean and free of any nicks or damage.
 4. Apply a small amount of grease in several locations to hold new water pump O-Ring in place. Install a new O-ring in groove of crankcase. Do not use RTV sealant in place of O-ring, or attempt to reinstall a used O-ring.
 5. Apply rubber lubricant to inner surfaces of short hose section. Assemble hose to outlet of water pump and secure with larger diameter clamp. Orient clamp so tangs extend out in 3 to 4 o'clock position.
 6. Slide smaller diameter clamp onto extruded end of formed metal tube and insert this end of tube into hose section. Position tube so its formed offset leads down and away from outlet, perpendicular to pump. Install clamp onto hose and position tangs of clamp parallel to those of first clamp.
 7. Holding pump assembly elevated, assemble transfer tube to 90° fitting in crankcase as follows:
 - a. For new/first time tube installation:
 1. Place a new ferrule/compression ring in 90° fitting of crankcase and loosely install hex cap onto threads of fitting.
 2. Insert plain end of transfer tube through hex and compression ring.
 - b. For reinstallation of an existing tube:
 1. Insert end of transfer tube, with compression ring, into 90° fitting of crankcase.
 2. Start hex cap onto threaded section of fitting.
- 90° fitting in crankcase is installed and sealed at factory, in a specific position. Special tools and procedures are involved. Do not loosen, remove, or alter mounting position of this fitting at any time.
8. Carefully push water pump down from raised position, thereby rotating tube 90° within end connections. Guide pump into position over O-ring; aligning two mounting pins and five screw hole locations. Start screws, with longer screw nearest pump outlet. Torque screws to 9.9 N·m (88 in. lb.) in sequence shown.
 9. Push down on formed tube and hold in this position to prevent it from pivoting upward when tightening hex cap. Torque hex cap to 22.6 N·m (200 in. lb.), to secure joint connection. Support fitting with a wrench while torquing, if possible, to prevent applying unnecessary pressure on fitting and joint. Check that formed tube and hose section have not been pulled up.
 10. Install drive belt onto cogged pulley of water pump, then around cam pulley. Slide cam pulley, with belt attached, down onto keyway end of camshaft. Be careful not to push key out of keyway and/or into seal when installing pulley.
 11. Check or use a feeler gauge to see that there is at least 3.17 mm (0.125 in.) clearance between underside of pulley, and hose, tube, and clamps. Remove pulley and reposition tube or clamps if required. Install flat washer and screw, to secure pulley in place. Torque screw to 9.9 N·m (88 in. lb.).

Reassembly

Flywheel/Ignition/Intake Manifold Components



A	Adapter	B	Thermostat Housing	C	Thermostat	D	Engine (Coolant) Temperature Sensor
E	Fuel Rail	F	Intake Manifold	G	Flywheel	H	Stator
I	Fuel Injector	J	Throttle Position Sensor	K	Torque Sequence	L	Speed Sensor
M	Speed Sensor Bracket						

Install Intake Manifold Assembly

1. Check that gasket surfaces of intake manifold and cylinder heads are clean and free of any nicks or damage.
2. Install new intake manifold gaskets onto port surfaces of cylinder heads.
3. Set intake manifold, with by-pass hose and wiring harness attached, down into position onto gaskets and cylinder heads. Install and finger tighten screws in their appropriate locations. Make sure clamps for wiring harness are positioned on long screw on each side. Torque six intake manifold mounting screws in two steps: first to 7.4 N·m (66 in. lb.), finally to 9.9 N·m (88 in. lb.) in sequence shown.
4. Install and tighten pipe plug or temperature warning switch, if removed previously from threaded port of intake manifold. Use pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) on threads. Torque to 22.6 N·m (200 in. lb.).

5. Connect wire leads to temperature warning switch, audible alarm, and/or Oil Sentry™ switch as equipped.

If thermostat and thermostat housing were removed from intake manifold, reassemble them at this time.

6. Make sure sealing surfaces of housing and manifold are clean and free of nicks or damage.
7. Install thermostat into recess in intake manifold, so larger spring end is down. Place a new thermostat housing gasket onto manifold surface, aligning screw holes. Make sure that one of notches in gasket is aligned with by-pass slot in manifold and thermostat housing. Do not use a substitute gasket.
8. Position thermostat housing on gasket and intake manifold. Notch in manifold, gasket and thermostat housing must all be aligned. Install and torque screws to 9.9 N·m (88 in. lb.).
9. Apply rubber lubricant to inside end of upper radiator hose, and install hose to thermostat housing, if separated for servicing. Secure with clamp. Make sure tangs of clamp point toward cylinder 1, away from fan.

Install Coolant By-pass Hose (If separated from intake manifold through individual component servicing)

1. If connector fitting for by-pass hose was removed from manifold, reinstall it at this time. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) onto threads and tighten, so fitting faces/points toward 2 side, long intake manifold screw.
2. Attach coolant by-pass hose to fittings in water pump and intake manifold. Secure with clamps.
3. Connect wire leads to temperature warning switch, audible alarm, and/or Oil Sentry™ switch, as equipped.

Install Stator Assembly

1. Place a small amount of pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) into holes for stator mounting screws. Position stator assembly onto mounting studs so leads are at bottom, and directed out toward cylinder 1 side, in 3 o'clock position. Align mounting holes and install screws. Torque each screw to 6.2 N·m (55 in. lb.).

Install Flywheel

	<p>⚠ CAUTION</p> <p>Damaging Crankshaft and Flywheel Can Cause Personal Injury!</p>
	<p>Using improper procedures can lead to broken fragments. Broken fragments could be thrown from engine. Always observe and use precautions and procedures when installing flywheel.</p>

NOTE: Before installing flywheel make sure crankshaft taper and flywheel hub are clean, dry, and completely free of lubricants. Presence of lubricants can cause flywheel to be overstressed and damaged when screw is torqued to specifications.

NOTE: Always use a flywheel strap wrench or holding tool to hold flywheel when tightening flywheel fastener. Do not use any type of bar or wedge to hold flywheel, as component damage and personal injury could result.

NOTE: Make sure flywheel key is installed properly in keyway. Flywheel can become cracked or damaged if key is improperly installed.

1. Install woodruff key into keyway of crankshaft. Make sure that key is properly seated and parallel with shaft.
2. Thread starter mounting bolts into hub of flywheel, or use flywheel puller to serve as a handle and set flywheel in place.
3. Install screw and washer.
4. Use a flywheel holding tool to hold flywheel and torque screw to 66.4 N·m (49 ft. lb.).
5. Using a light, visually check that sufficient clearance exists between cooling system components and bottom of flywheel.
 - If clearance is OK, continue with installation of ignition modules.
 - If clearance is insufficient or contact is noted, remove flywheel and adjust as required. Reinstall flywheel and recheck for adequate clearance.

Install Speed Sensor

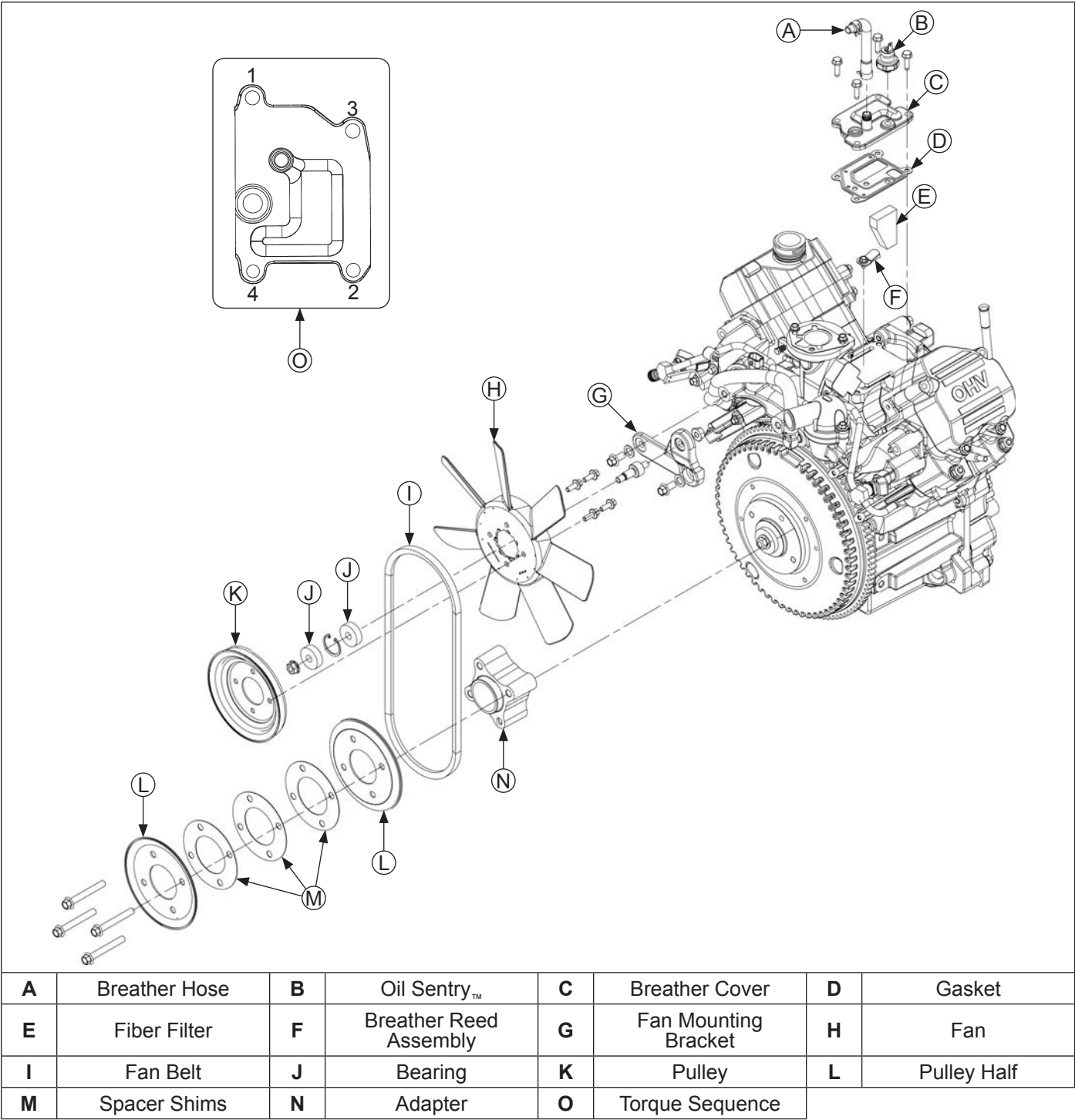
1. Secure speed sensor bracket with speed sensor to water pump with screws. Torque to 10.7 N·m (95 in. lb.) into new holes and 7.3 N·m (65 in. lb.) into used holes.
2. Check mounting and air gap of sensor. It must be 1.5 mm ± 0.25 mm (0.059 ± 0.010 in.).

Install Spark Plugs

1. Check gap using wire feeler gauge. Adjust gap, see specification table for adjustment.
2. Install plug into cylinder head.
3. Torque plug to 20 ft. lb. (27 N·m).

Reassembly

External Engine Components



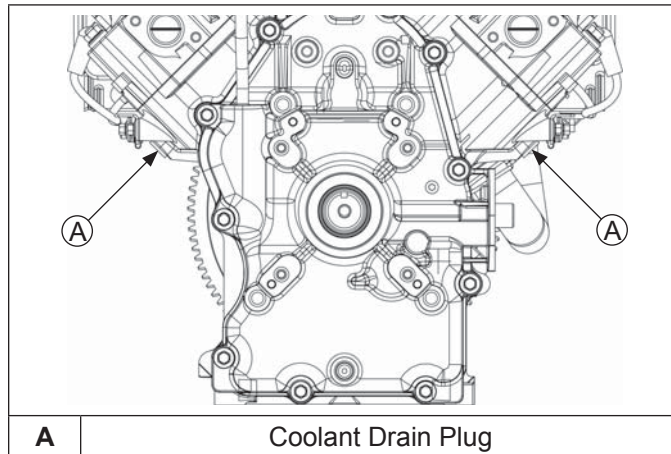
Install Reed and Breather Cover Assembly

1. Make sure sealing surfaces of crankcase and breather cover are clean and free of all old gasket material. Clean with an aerosol type gasket remover or cleaning solvent. DO NOT scrape surfaces as this can result in leakage.
2. Check to make sure there are no nicks or burrs on sealing surfaces.
3. Install breather reed and breather reed retainer onto crankcase and secure with screw. Hold assembly in line when tightening. Torque screw to 3.9 N·m (35 in. lb.).
4. Install breather filter into cavity in crankcase.
5. Carefully install breather cover gasket and breather cover onto crankcase.
6. Install and torque four breather cover screws to 7.3 N·m (65 in. lb.) in sequence shown.

7. Install pipe plug or Oil Sentry™ switch (as equipped), into tapped breather port if removed earlier. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to threads. Torque to 4.5 N·m (40 in. lb.). If Oil Sentry™ switch is mounted to side of crankcase, torque switch to 12.4 N·m (110 in. lb.).
8. If vacuum fitting was removed from crankcase (vacuum fuel pump), apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to threads of fitting and install. With crankcase upright, fitting must point to 1:30 position.

Reinstall Coolant Drain Plugs

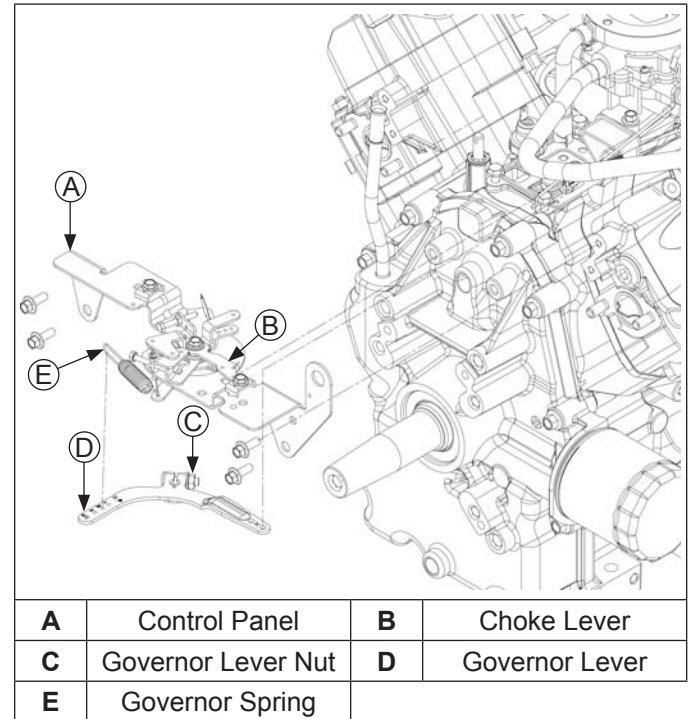
Coolant Drain Plug Details



1. Reinstall brass coolant drain plugs in sides of crankcase, (and also cylinder head plugs, if removed during head servicing). Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to threads and reinstall plugs. Torque plugs to 36.7 N·m (325 in. lb.).

Install External Governor Controls and Main Control Bracket

Control Panel Details



1. Install governor lever onto governor cross shaft. If separated, connect throttle link to governor lever with plastic bushing. Hook dampening spring into small (middle) hole.
2. Move governor lever TOWARDS intake manifold as far as it will go (wide open throttle) and hold in this position.
3. Insert a nail into hole in cross shaft and rotate shaft COUNTERCLOCKWISE as far as it will turn. Then torque nut to 6.8 N·m (60 in. lb.).
4. Connect choke lever of main control bracket to choke linkage from intake manifold. Mount main control bracket to cylinder heads with four screws. Torque screws to 10.7 N·m (95 in. lb.) into new holes, or 7.3 N·m (65 in. lb.) into used holes.
5. Connect dampening spring to throttle lever. Connect governor spring from throttle control bracket to appropriate governor lever hole.

Install Lower Crankshaft Pulley, Pulley Adapter, and Cooling Fan Assembly

NOTE: Do not assemble lower pulley with belt between pulley halves, as pinching of belt or damage to pulley can occur.

1. Make sure shoulder of flywheel hub and adjacent face surface are clean and free of any nicks or damage.
2. Install crankshaft pulley adapter onto flywheel hub, so offset for pulley is out, and holes are aligned. Make sure adapter rests squarely on face of flywheel.

Reassembly

3. Assemble front and rear pulley halves placing shims as indicated.
 - a. For a new belt: Assemble with 2 or 3 shims between pulley halves, and remaining shim (if any) on outside (front) of outer pulley half.
 - b. For a used belt: Assemble with 2 shims between pulley halves and remaining shim(s) on outside (front) of outer pulley half.

Install and snug pulley assembly. Final belt tension and pulley assembly will be made after fan/upper pulley assembly is installed.

4. Install upper fan mounting bracket to intake manifold with screws.

Torque:

M6 Screws to 7.3 N·m (65 in. lb.)

M8 Screws to 24. 4 N·m (216 in. lb.)

By-pass hose and wires must be positioned within cutout in intake manifold. Be careful not to pinch harness wires between bracket and intake manifold when tightening.

5. If disassembled, reassemble fan and pulley assembly as shown.

Make sure one flat washer is placed between bearings in hub. Other washer is located under front nut. Torque fan/pulley/hub mounting screws to 6.8 N·m (60 in. lb.).

6. If fan shaft was removed from upper mounting bracket, apply Loctite® 242® to rear threads. Install and torque rear nut to 15.8 N·m (140 in. lb.). Install fan and pulley assembly onto fan shaft and upper mounting bracket.
7. Apply Loctite® 242® to front threads of fan shaft. Install flat washer and nut to secure. Torque nut to 15.8 N·m (140 in. lb.).
8. Carefully work belt into place on pulleys. Check belt tension. There should be no more than 9.53 - 12.7 mm (3/8" - 1/2") belt deflection per side with 10 lbs. of applied tension.

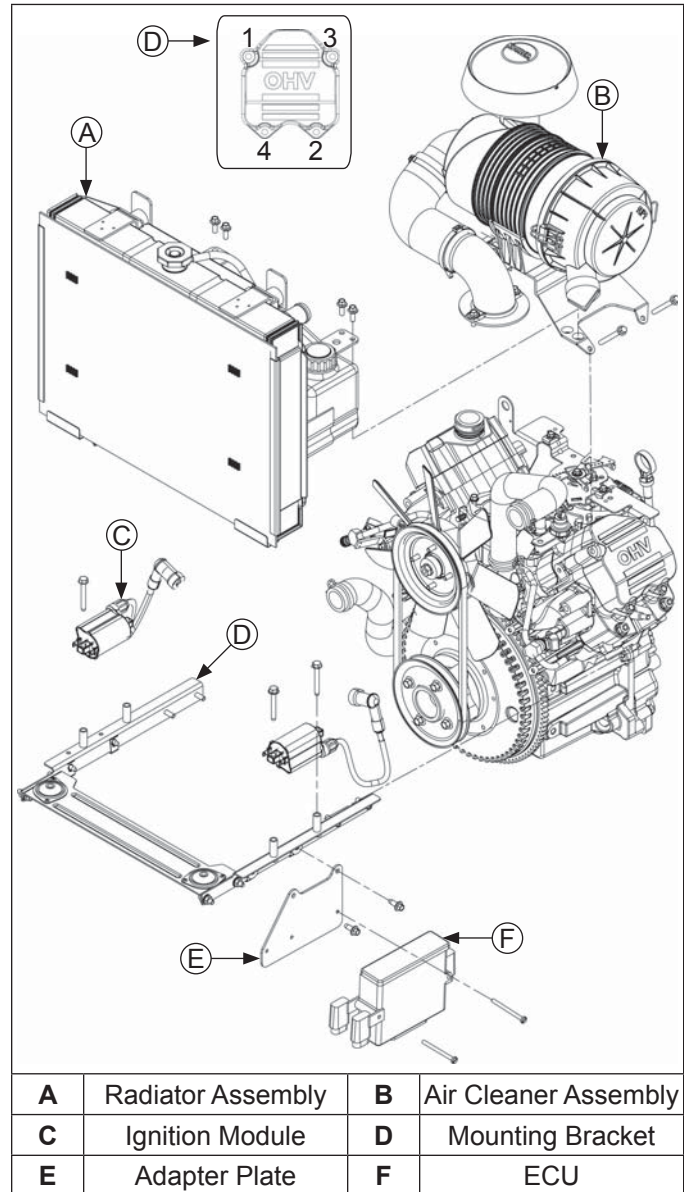
If belt tension is low, remove belt and relocate a shim from between pulley halves to outside (front). Reinstall belt and recheck tension. Repeat procedure until correct tension is reached. If shims have all been moved to outside, and belt is still too loose, replace belt.

When proper tension is obtained, individually remove each capscrew, apply Loctite® 242® to threads of lower pulley and reinstall. Torque four bolts in a criss-cross sequence to 24.3 N·m (215 in. lb.).

9. Mount RH and LH lower radiator supports with cross support bracket attached, to crankcase, using screws. Snug screws only at this time.

Install Air Cleaner Assembly

External Engine Components



1. Install a new elbow adapter gasket onto intake manifold adapter.
2. Set air cleaner/mounting bracket assembly, with hose and elbow attached, in position on engine. Align all of mounting holes. Start and finger tighten each of mounting screws. Make sure fuel line is outside of main bracket when installed.
3. Torque elbow mounting screws to 7.3 N·m (65 in. lb.). Then torque eight valve cover mounting screws to 6.2 N·m (55 in. lb.) in sequence shown.
4. Torque rectifier-regulator ground wire screw to intake manifold to 7.3 N·m (65 in. lb.).
5. Secure ECU adapter plate to mounting bracket. Torque screws to 7.3 N·m (65 in. lb.). Reconnect connector to ECU.

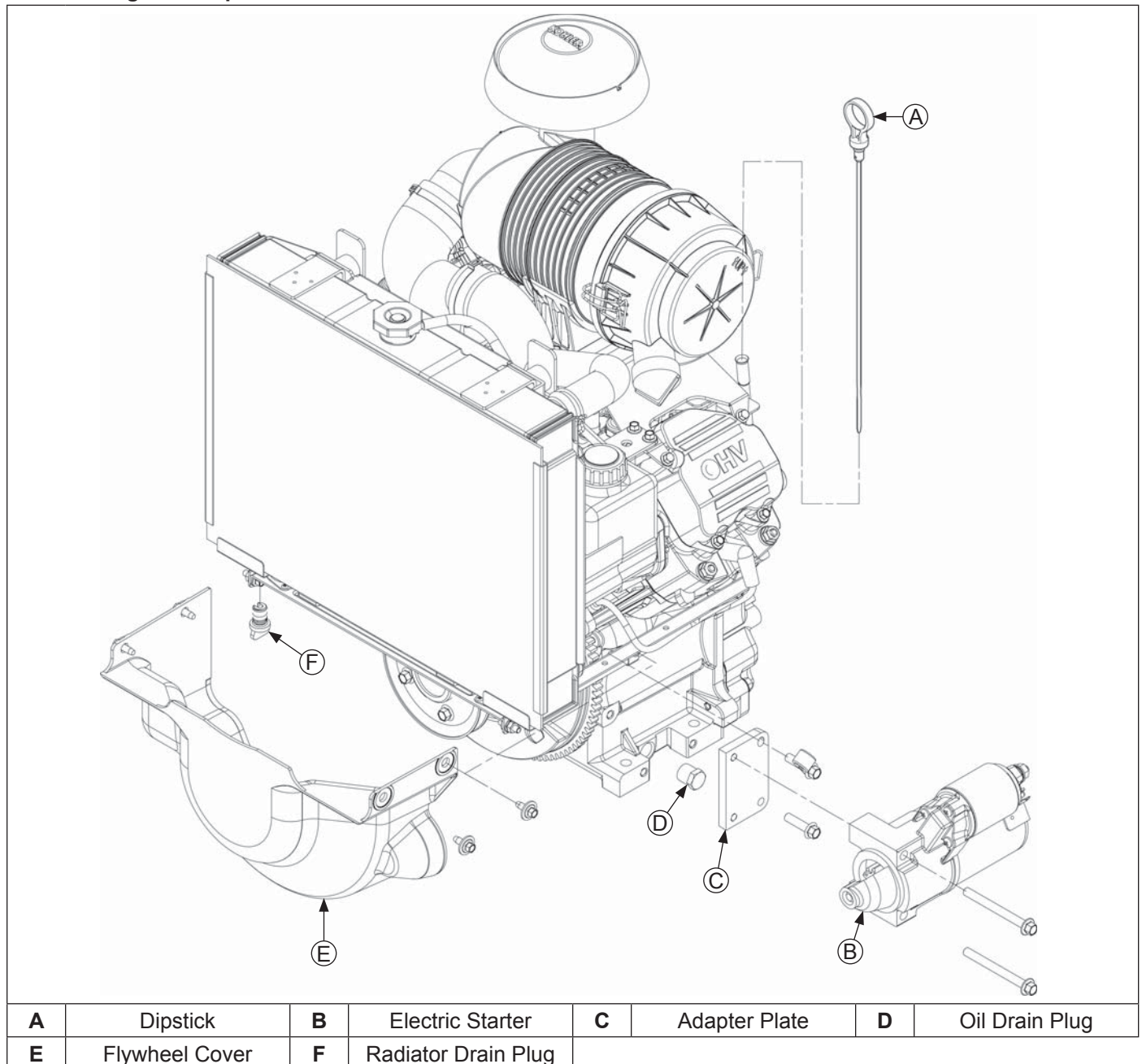
6. If removed, install rain cap and secure with clamp. Check position of dust ejector, it should face downward. Adjust end cap position as required.
5. Connect wires for audible alarm, if used.

Install Radiator Assembly

1. Reassemble components of radiator assembly, including upper and lower radiator hoses. Rubber lubricant may be applied to inner surfaces of hoses to make installation easier. Secure with hose clamps.
2. Tighten radiator drain plug.

3. Carefully set radiator assembly into place, guiding lower radiator hose inside RH support bracket. Make sure that cooling fins do not come in contact with fan blades as radiator is installed.
4. Position upper radiator support brackets on top of air cleaner mounting bracket. Install and finger tighten four mounting screws.
5. Connect upper and lower radiator hoses to inlets of radiator and water pump. Secure with hose clamps. Make sure tangs of upper clamp face away from fan.
6. Check for adequate clearance between fan and shroud. Adjust lower radiator supports as required, then torque four mounting screws to 9.9 N·m (88 in. lb.).

External Engine Components



Reassembly

7. Hold radiator assembly in position; then torque screws securing two upper radiator supports to 9.9 N·m (88 in. lb.).
8. If securing upper brackets to top radiator mounts were loosened, torque to 9.9 N·m (88 in. lb.).

Install Ignition Modules

1. Install ignition module to mounting bracket. Position spacer between ignition module and mounting bracket, and torque screws to 6.2 N·m (55 in. lb.) into new hole or 4.0 N·m (35 in. lb.) into used hole.
2. Repeat step 1 for other ignition module.
3. Connect leads to ignition modules.

Install Starter Adapter

1. Install starter adapter to crankcase, so cutout is offset down and facing away from flywheel side. Install mounting screws, and position clamp for stator leads on upper screw. Torque screws to 15.3 N·m (135 in. lb.).
2. Place stator leads within clamp and close loop.
3. If violet B+ charge lead is separate from main harness, secure it to wiring harness with a tie strap, directly above clamp.

Install Starter Assembly

NOTE: Stator leads and rectifier-regulator plug must be above starter.

1. Mount starter to adapter plate using screws.
2. Make sure starter is square to flywheel, and torque screws to 15.3 N·m (135 in. lb.).
3. Attach leads to appropriate starter solenoid terminals.
4. To avoid damage or breakage, do not over-tighten nut when attaching positive battery cable. Torque nut to 6-9 N·m (53-79 in. lb.).

Install Lower Flywheel Cover, Rectifier-Regulator and Mounting Plate

1. Install/make sure small metal spacers are positioned in mounting holes of lower flywheel cover.
2. Attach lower flywheel cover to cylinder 2 (oil filter) side lower radiator support bracket, using M6 screws and flat washers. Finger tighten only at this time.
3. Align lower flywheel cover with cylinder 1 (starter) side lower radiator support bracket holes. Position rectifier-regulator mounting plate, behind cover and install remaining two screws or nuts and flat washers. Torque four fasteners to 9.9 N·m (88 in. lb.). If screws and Timmerman nuts/clips are used torque to 2.2-2.8 N·m (20-25 in. lb.).
4. If removed, mount rectifier-regulator to plate with two screws and attach connector plug.

Install Muffler

1. Install new exhaust gaskets and attach muffler and mounting hardware. Torque screws to 9.9 N·m (88 in. lb.).
2. Install nuts to exhaust studs. Torque nuts to 24.4 N·m (216 in. lb.).

Install Oil Filter and Fill Crankcase with Oil

NOTE: Make sure both oil drain plugs are installed and torqued to specifications to prevent oil leakage.

1. Install oil drain plug(s). Torque plug(s) to 13.6 N·m (10 ft. lb.). If oil drain valve is used, make sure valve body is closed and cap is on.
2. Place new filter in shallow pan with open end up. Fill with new oil until oil reaches bottom of threads. Allow 2 minutes for oil to be absorbed by filter material.
3. Apply a thin film of clean oil to rubber gasket on oil filter.
4. Refer to instructions on oil filter for proper installation.
5. Fill crankcase with new oil. Level should be at top of indicator on dipstick.
6. Reinstall oil fill cap/dipstick and tighten securely.

Install Coolant

1. Use equal parts of ethylene glycol (antifreeze) and water only. Distilled or deionized water is recommended, especially in areas where water contains a high mineral content. Propylene glycol based antifreeze is not recommended.
2. Fill cooling system, through radiator, with coolant mix. Allow coolant to drain into lower areas. Fill overflow reservoir midway between FULL and ADD marks, then install radiator and reservoir caps.

Reconnect Battery and Spark Plug Leads

Connect leads to spark plugs. Reconnect positive (+) battery lead first, and negative (-) lead last when connecting battery.

Testing Engine

It is recommended engine be appropriately secured and operated on a test stand or bench, prior to installation in application.

1. Make sure all hardware is tightened, and hose clamps are properly secured.
2. Set up engine on a test stand. Install an oil pressure gauge. Start engine and check to be certain that oil pressure (20 psi or more) is present. Run for 5-10 minutes between idle and mid-range.
3. Check all cooling system components and joint connections for leaks.
4. Make sure maximum engine speed does not exceed 3750 RPM (no load). Adjust throttle and high speed stop as necessary. Refer to Fuel System.
5. Place throttle control into idle or slow position and check low idle speed (RPM). Refer to Fuel System if adjustment is required.
6. Stop engine.
7. Recheck oil and coolant levels. Oil level should be at F mark on dipstick, and coolant level in reservoir should be midway between ADD and FULL marks. Add additional amounts as required.



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